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MANNED ORBITAL SYSTEMS CONCEPTS STUDY

BOOK 4 - PROGRAMMATICS FOR EXTENDED-DURATION MISSIONS

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY-WEST

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FOREWORD

The basic MOSC Study encompassed a 9-month effort which examined the requirements for and established the definition of a cost-effective orbital facility concept capable of supporting extended manned operations in Earth orbit beyond those visualized for the 7- to 30-day Shuttle/Spacelab system. The study activity was organized into the following four tasks:

Task 1 Requirements Derivation

Task 2 Concepts Identification

Task 3 System Analysis and Definition

Task 4 Programmatics

In Task 1 the payload and mission requirements were examined for manned orbital systems with operational capabilities beyond those presently planned for the Shuttle/Spacelab program. These research activities were translated into characteristics of representative grouped payloads, including physical and operational parameters. The manned approach to research implementation was emphasized, as well as the lessons learned from previous Apollo and Skylab experience.

The second study task originally centered about the identification and definition of attached and free-flyer manned concepts to satisfy the requirements evolved from Task 1. Based upon the material presented in the first formal briefing, the study was redirected to conclude work on the attached mode of operation and concentrate the remaining effort on free-flying concepts.

Task 3 provided detailed definition of the baseline MOSC concept and the critical subsystem areas to a level required for subsequent programmatic analyses.

Task 4 developed project cost and schedule milestones related to the baseline concept in order to provide NASA with data useful for long-range planning activities and program analyses.

The study results are reported in four books. Book 1 presents an executive summary and overview of the study; Book 2 describes the derivation of requirements; Book 3 describes configuration development; and Book 4 describes the programmatic analyses.

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LIST OF ABBREVIATIONS USED IN THIS BOOK

AM	Airlock Module
ATM	Apollo Telescope Mount
ATP	Authority to Proceed
CDR	Critical Design Review
CER	Cost Estimating Relationship
C&W	Caution and Warning
C/O	Checkout
CY	Calendar Year
DDT&E	Design, Development, Test, and Evaluation
DT	Development Test
ECLS	Environmental Control and Life Support
ED&D	Engineering Design and Development (No hardware)
EOC	Elements of Cost
ENGR	Engineering
ER	Engineering Release
FAB	Fabrication
FACI	First Article Configuration Inspection
FO	Flight Operations
FRR	Flight Readiness Review
FY	Fiscal Year
GTH	Ground Test Hardware
HM	Habitability Module
IOC	Initial Operational Capability
LEADER	Life-Cycle Estimates Analytically Derived from Engineering Relationships
LM	Logistics Module
LO	Launch Operations
MDA	Multiple Docking Adapter
MDAC	McDonnell Douglas Astronautics Company
MOS	Manned Orbital System
MOSC	Manned Orbital Systems Concept
MSK	Major Subcontractors
MSS	Modular Space Station
MUX	Multiplexer
OWS	Orbital Workshop

PCM	Pulse Coded Modulation
PM	Payload Module Shell
PDR	Preliminary Design Review
PLSS	Personal Life Support System
PRR	Preliminary Requirements Review
QT	Qualification Test
SE&I	Systems Engineering and Integration
SOW	Statement of Work
SM	Subsystems Module
SRT	Supporting Research and Technology
WBS	Work Breakdown Structure

Section 1
SUMMARY

This volume presents the cost estimates, schedule data, and funding distributions generated in the Manned Orbital Systems Concepts (MOSC) Study. The overall objectives of this pre-Phase A study were to examine the requirements for, and to describe, a cost-effective concept for an orbital facility capable of supporting manned operations in Earth orbit beyond the 7-to-30-day mission duration provided by the Shuttle/Spacelab system.

The cost, schedule, and other programmatic data in this volume were developed to provide NASA with information useful for their long-range planning activities. The major portion of the data documented and discussed in this volume consists of project- and system-level schedule and funding information and also project-, system-, and subsystem-level cost summaries. The MDAC LEADER*II Costing System was used to generate and distribute this data on the NASA Cost Data Forms A(1), A(2), A(3), and C, according to the NASA-approved work breakdown structure (WBS) hierarchy.

A large part of this data was derived directly from information on existing hardware with characteristics similar to those required for the proposed system/subsystems and from detailed data developed during the Phase B Space Station Definition** study. Although the data in this report represents preliminary planning data, it is believed to merit a higher level of confidence than is normally assigned to pre-Phase A values because of the supplemental material used. The confidence level will be increased even further when cost data become available from the vendors and contractors supplying hardware for the ongoing Spacelab and Orbiter programs.

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*Life-cycle Estimates Analytically Derived from Engineering Relationships

**NASA Phase B Space Station Definition Study, Contract NAS 8-25140, McDonnell Douglas Astronautics Company, Huntington Beach, California 1970-72

The baseline four-man MOSC facility consists of four cylindrical modules configured as shown in Figures 1-1 through 1-4. (Additional detail is presented in the technical descriptions in Books 2 and 3.) Each orbital facility set is provided with an extra logistics module (LM) and payload module (PM) shell. This permits one of each of these modules to be available on Earth, and permits stowing supplies in one LM and reconfiguring the experiment payload in one PM while the other LM and PM modules are in orbit. Two complete sets of orbital hardware — one for a 28.5° inclination orbit and one for polar orbit, with six modules each for a total of 12 modules — are included in the cost and funding estimates, which reflect the design, schedule, and other programmatic decisions detailed in later sections of this volume.

Based on the costing ground rules and methodology summarized in Figure 1-5 and described in more detail in Section 2, the project cost for the baseline 4-man MOSC is estimated to be $1,184.6 million. This cost figure is the sum of the following DDT&E, Production, and Operations costs.

Phase	FY 1975 $ Millions	Percent
DDT&E	571.4	48.2
Production	313.6	26.5
Operations	299.6	25.3
	$1,184.6	100.0

The DDT&E figure reflects extensive use of Spacelab and Orbiter hardware; a program management concept that exercises tight control of program changes, (e.g., only safety-related change orders once the program is initiated); and a test plan that provides for multiple use of test articles. The production figure includes the hardware cost for two complete sets of orbital facilities (total of 12 modules) and the initial spares for that hardware. The operations cost includes the cost of the simulator/trainer, the cost of the consumables required for five years of operation of the facility in a 28.5° orbit, and three years' operation of the polar facility. Operation cost estimates assume that approximately one-third of the MOSC ground operations crew at the launch site

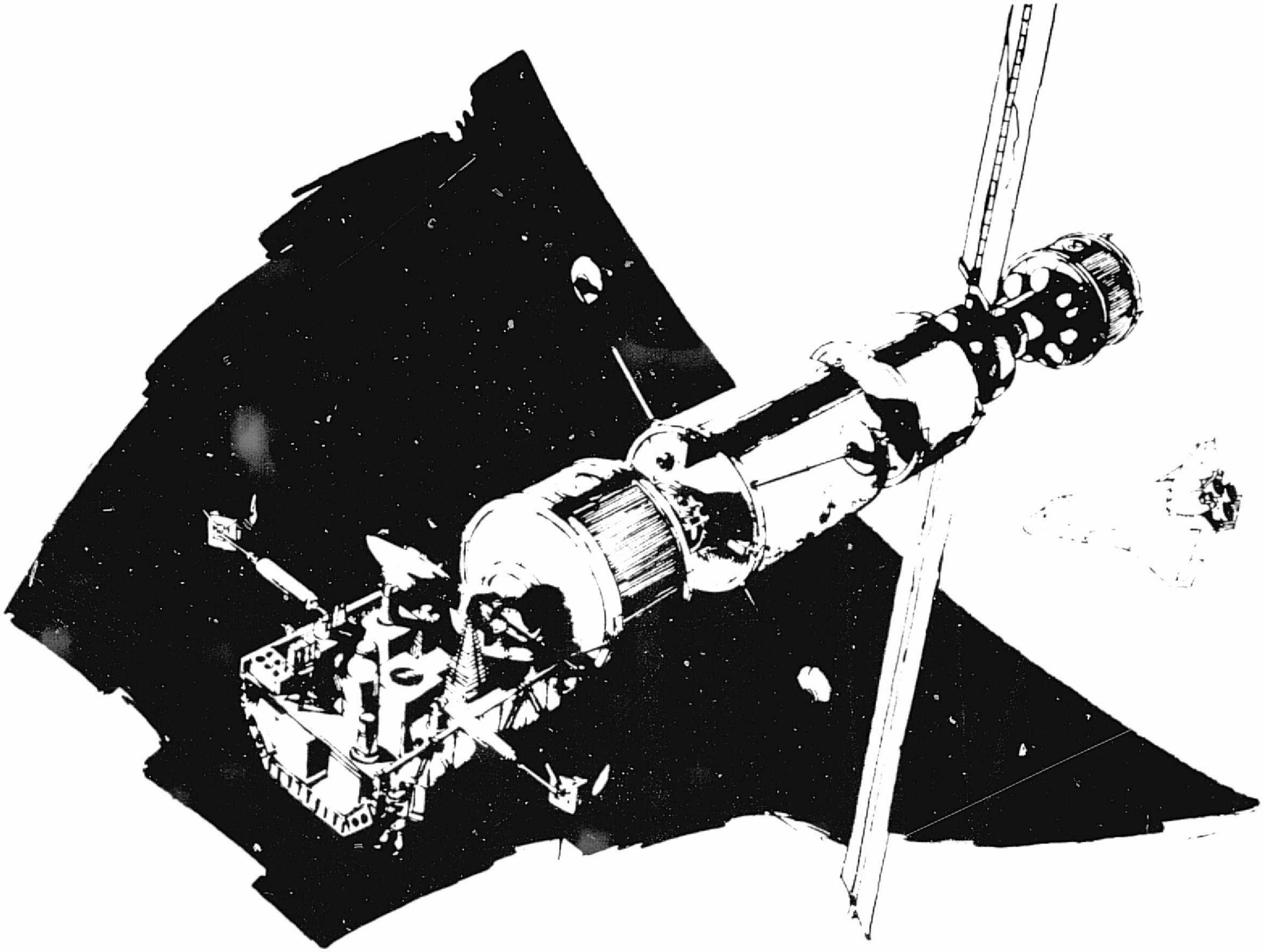

Figure 1-1. Manned Orbital Facility

FEATURES	CAPABILITIES
• MANNED ONBOARD SUPPORT TO PAYLOADS	INITIAL ORBITAL FACILITY IN 1985 WITH FOUR-MAN CREW; POTENTIAL FACILITY GROWTH FOR CREW OF 12 BY 1990
• PAYLOAD TRAFFIC TO ORBIT	NOMINAL PM REPLACEMENT AND/OR RESUPPLY AT 90-DAY INTERVALS; OTHER PAYLOAD SUPPORT INTERVALS AVAILABLE AS REQUIRED
• ONBOARD PAYLOAD VOLUME	PRESSURIZED MODULES AVAILABLE TO ACCOMMODATE UP TO 5,000 CUBIC FEET OF PAYLOAD EQUIPMENT AND SUPPLIES; MULTIPLE MODULES AND/OR LAUNCHES AVAILABLE TO HANDLE LARGE PAYLOADS
• ELECTRICAL POWER	8.5 KW AVAILABLE FOR PAYLOADS
• ENVIRONMENT	CABIN PRESSURE 14.7 PSI WITH SHIRTSLEEVE ENVIRONMENT – FULL TEMPERATURE AND HUMIDITY CONTROL
• DATA MANAGEMENT AND COMMUNICATIONS	CONTINUOUS GROUND CONTACT; REAL-TIME OR DELAYED TRANSMISSION
• SPACE-PLATFORM ORIENTATION	ALL-ORIENTATION VEHICLE STABILIZED TO 0.1° WITH HORIZON AND STELLAR ATTITUDE REFERENCE

Figure 1-2. Manned Orbital Facility Overview

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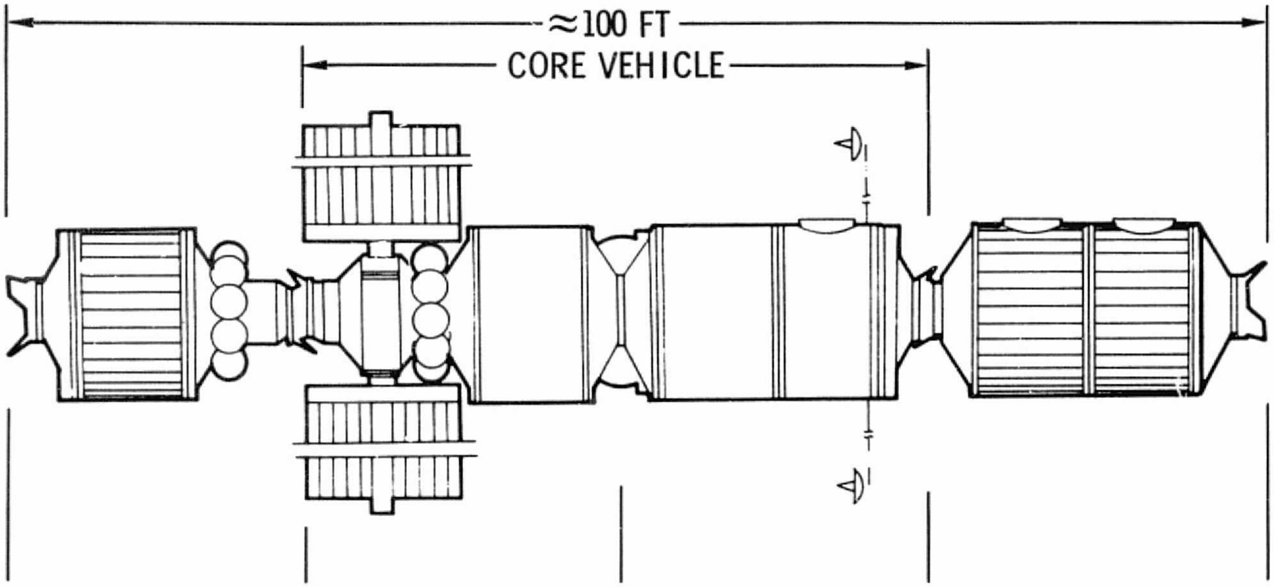

ELEMENT	LOGISTICS MODULE (LM)	SUBSYSTEMS MODULE (SM)	HABITABILITY MODULE (HM)	PAYLOAD MODULE (PM)
FUNCTION	FLUID SUPPLY, BULK CARGO, WASTE STORAGE	ELECTRICAL POWER, STABILIZATION, COMMUNICATIONS, HYGIENE	LIVING QUARTERS, PAYLOAD MONITORING STOWAGE, GALLEY	EXPERIMENTS, APPLICATIONS
LENGTH (FT)	22.7	25.8	24.7	11.5 TO ≈ 60
WORKING VOLUME (FT^3)	1,618	1,620	2,450	1,500 TO ≈ 5,000
NUMBER PER ORBITAL FACILITY SET	2	1	1	2 (SHELLS ONLY)

Figure 1-3. MOSC 4-Man Baseline Facility Outboard Profile

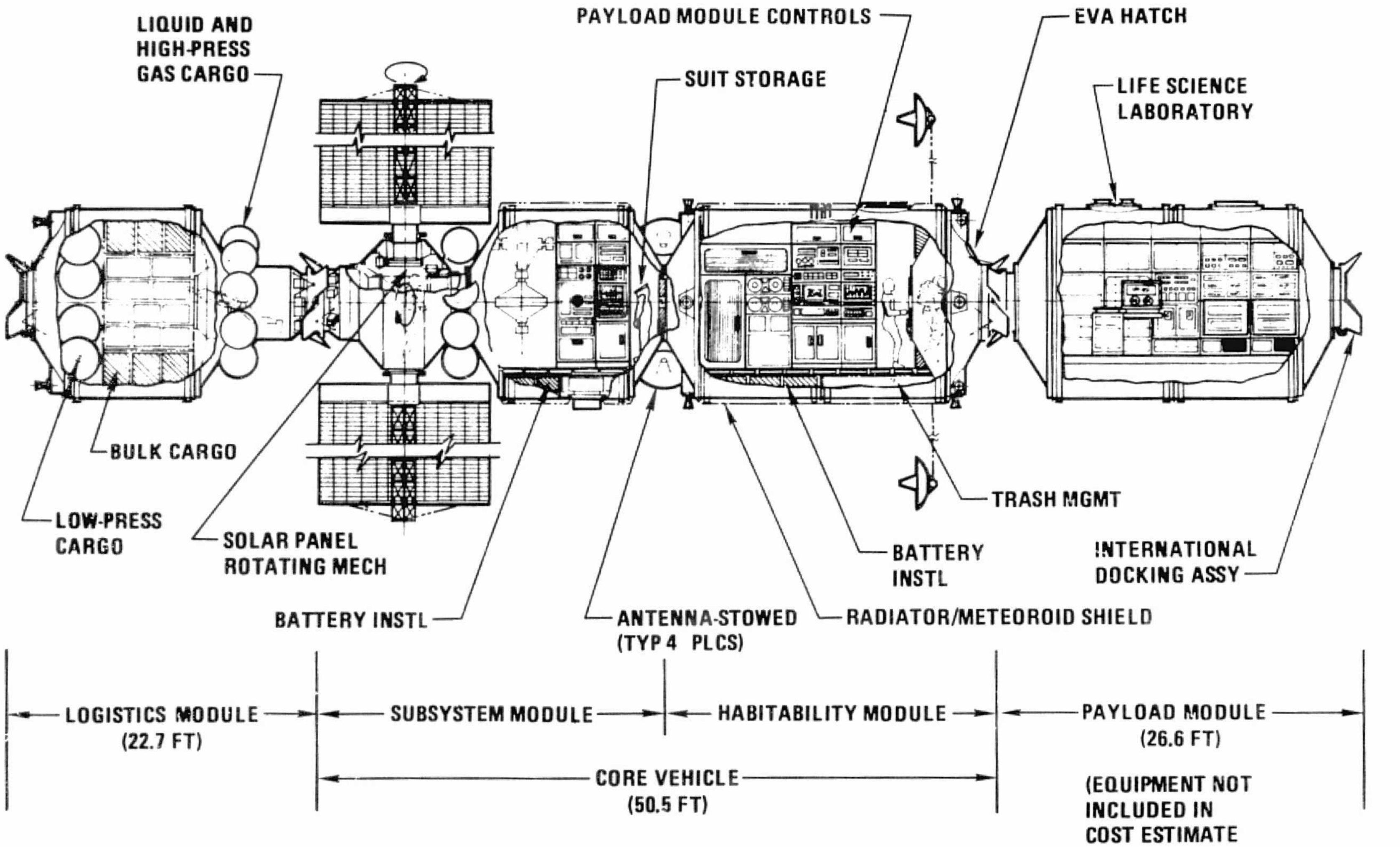

Figure 1-4. MOSC 4-Man Baseline Facility Internal Configuration

AUSTERE PROJECT APPROACH

- STREAMLINED CONTRACTOR MANAGEMENT
- MAXIMUM USE OF EXISTING HARDWARE AND TECHNOLOGY

  SPACELAB STRUCTURAL SHELL
  ORBITER AVIONICS AND CREW SUPPORT EQUIPMENT
  NO SRT REQUIRED
  MINIMUM DEVELOPMENT TEST PROGRAM

- RIGID CONTROL OF PROGRAM CHANGES

OPTIMIZED HARDWARE QUANTITIES – 28.5° AND POLAR FACILITIES

- TWO HABITABILITY AND SUBSYSTEM MODULES
- FOUR LOGISTICS MODULES AND PAYLOAD SHELLS
- ONE HIGH-FIDELITY TRAINER/SIMULATOR

COST-EFFECTIVE SCHEDULE

- 5-YEAR DEVELOPMENT: ATP – JAN 80; IOC – DEC 84
- 5 YEAR OPERATIONS: 2-YEAR GAP BETWEEN 28.5° AND POLAR OPERATIONS

COST ESTIMATES (FY75 DOLLARS)

- INCLUDE

  DDT&E, PRODUCTION AND OPERATIONS PROGRAM PHASES
  HARDWARE AND NON-HARDWARE FUNCTIONS
  PRIME CONTRACTORS AND SUBCONTRACTOR EFFORT

- EXCLUDE

  MOSC FLIGHT CREW
  NASA GROUND OPERATIONS
  SHUTTLE LAUNCH COSTS
  NASA PROGRAM MANAGEMENT AND SUPPORT COSTS
  EXPERIMENT AND EXPERIMENT INTEGRATION
  PRIME CONTRACTOR FEE

Figure 1-5. MOSC Ground Rules and Programmatic Assumptions

will be contractor personnel. These estimates also provide that a minimal number of contractor personnel (approximately 20) will be available to support mission control activities during the entire operational phase. By NASA direction, the estimate excludes all costs for NASA personnel, including flight crews, NASA institutional base, Shuttle, and Shuttle-related costs.

Figure 1-6 proportions the $1. 184. 6 MOSC project cost by phase and by system level elements. (Note: The WBS nomenclature is explained in Section 2 and defined in Appendix A.) This figure shows that the MOSC modules represent 51 percent of the project cost, while the other system elements account for the remaining 49 percent. Figure 1-7 presents a further breakdown of the costs included in each phase. Table 1-1 summarizes the life-cycle costs for the MOSC project.

Table 1-1
PROJECT LIFE-CYCLE COST SUMMARY, BASELINE 4-MAN MOSC CONFIGURATION, 28. 5° AND POLAR FACILITIES

WBS No.	Description	Phase (Millions FY 1975 Dollars)			Total Project
		DDT&E	Prod	Ops	
10	Project Management	33.3	14.9	14.0	62.2
20	Systems Engineering and Integration	94.2	100.6	8.0	202.8
30	MOSC Modules	293.9	197.8	112.4	604.1
40	Experiments	-	-	-	-
50	Experiment Integration	-	-	-	-
60	Ground Support Equipment	62.0	0.3	12.3	74.6
70	System Test	83.7	-	-	83.7
80	Logistics	-	-	111.1	111.1
90	Facilities	4.3	-	-	4.3
100	Ground Operations	-	-	41.8	41.8
110	Flight Operations (NASA)	-	-	-	-
	TOTAL	571.4	313.6	299.6	1,184.6

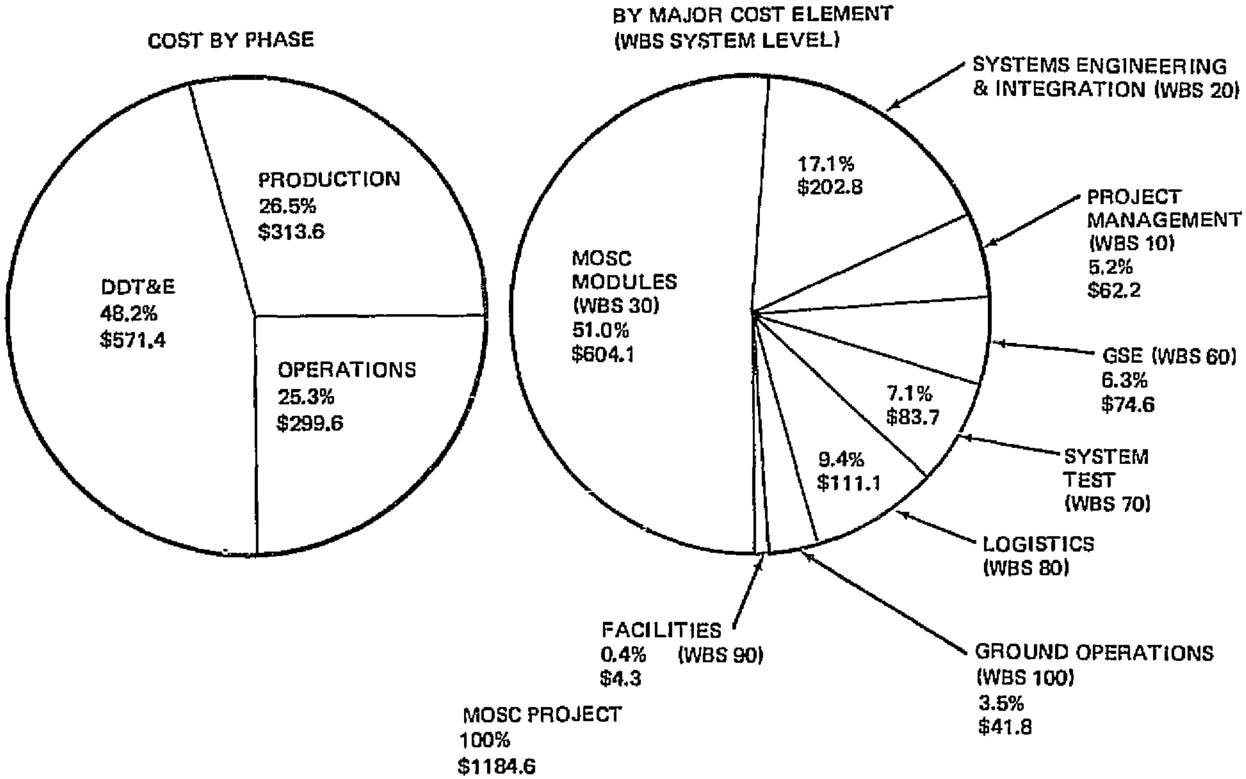

Figure 1-6. Project Cost, MOSC 4-Man Baseline Configuration, 28.5° and Polar Facilities (Millions of FY 1975 Dollars)

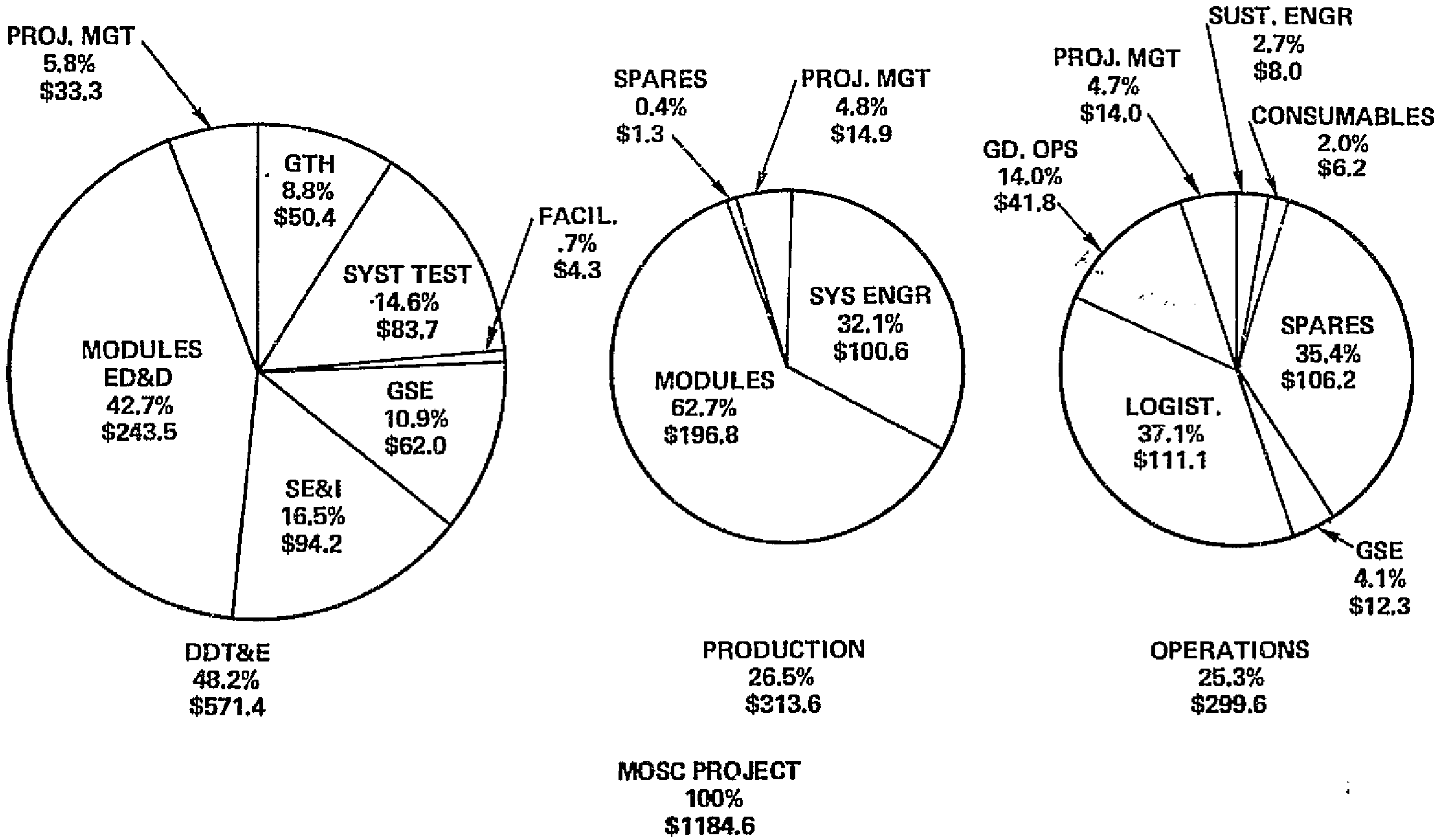

Figure 1-7. Major Cost Elements by Phase, MOSC 4-Man Baseline Configuration, 28.5° and Polar Facilities (Millions of FY 1975 Dollars)

Table 1-2 summarizes the average unit production cost for each module. These values include each module's share of systems engineering and project management cost. The table also shows how the modules combine to give an average cost for each orbital facility of $156.1 million.

Table 1-2
AVERAGE UNIT PRODUCTION COSTS,
BASELINE 4-MAN MOSC CONFIGURATION

Module	Average* Unit Cost	Quantity per Facility	Cost per* Facility Set	Percent of Facility Set
Logistics	11.7	2	23.4	14.9
Habitability	45.8	1	45.8	29.2
Subsystems	80.2	1	80.2	51.2
Payload (Shell only)	3.7	2	7.4	4.7
	Average cost of Facility		156.8	100.0

*Millions of FY 75 dollars

The MOSC project schedule for the baseline 4-man configuration, Figure 1-8, is predicated upon the ground rules and assumptions detailed in Section 2. The symbols and abbreviations used in Figure 1-8 are as follows:

⏏	-	Spacecraft Operational Launch
▲	-	Milestone Event
△	-	Shipment and Delivery
ATP	-	Authority to Proceed
CDR	-	Critical Design Review
C/O	-	Checkout
DT	-	Development Test
ER	-	Engineering Release
FAB	-	Fabrication
FACI	-	First Article Configuration Inspection
FO	-	Flight Operations
FRR	-	Flight Readiness Review
LO	-	Launch Operations
MOS	-	Manned Orbital System
MSK	-	Major Subcontractor
QT	-	Qualification Test
PDR	-	Preliminary Design
PRR	-	Preliminary Requirements Review
XXXX	-	To Be Determined (TBD)

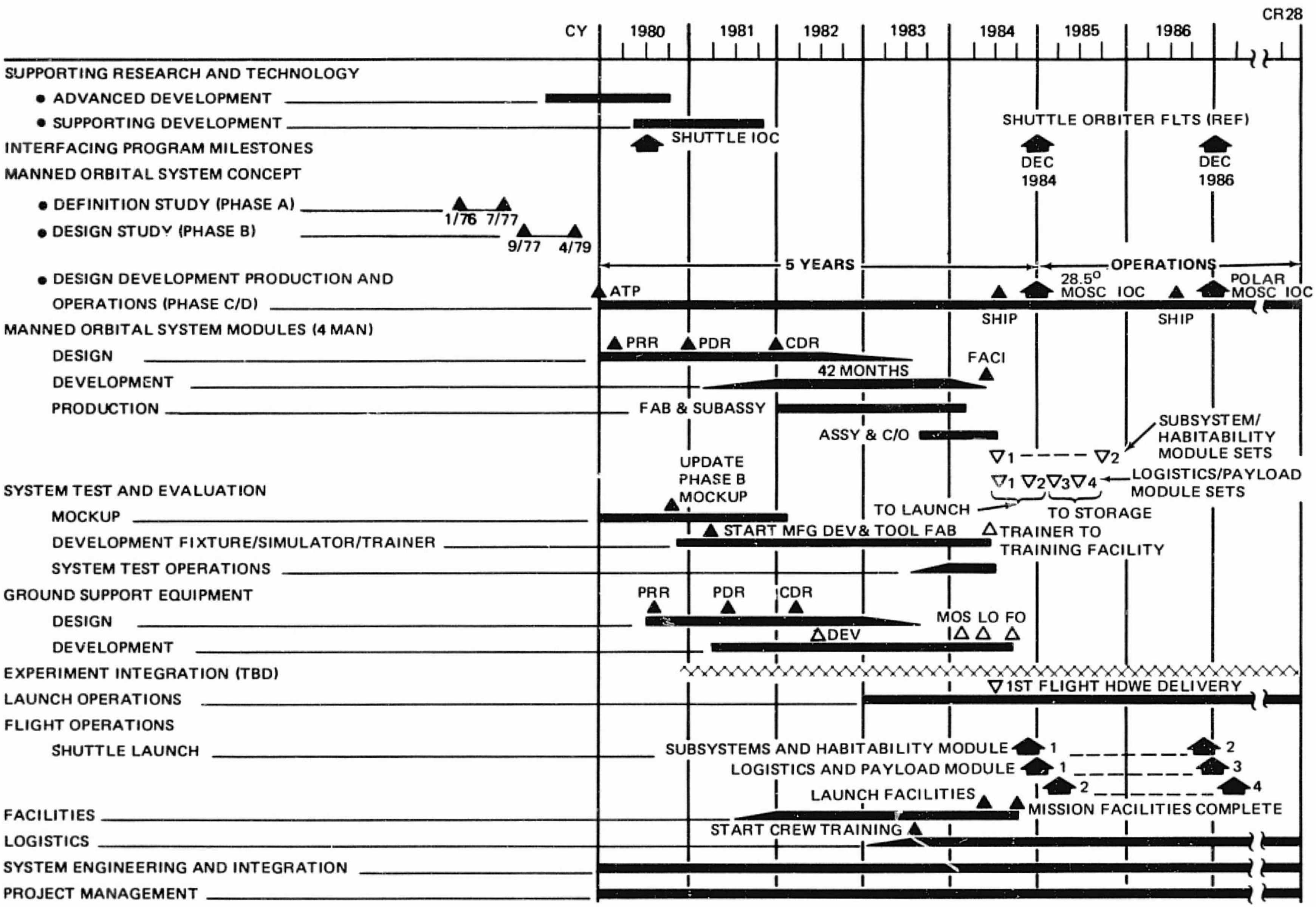

Figure 1-8. MOSC 4-Man Baseline Configuration Project Schedule

A five-year, funding-constrained development schedule is postulated. It assumes that the MOSC Phases C/D (ATP) starts on 1 January 1980 and identifies that achievement of initial operational capability (IOC) in a 28.5° orbit in late December 1984. The IOC data for the polar orbit facility is two years later, December 1986. Operations continue five years for the 28.5° facility and three years for the polar facility — to January 1990. Design, development, and test schedules, as well as the cost estimates, assume that selected hardware developed for the Spacelab and Space Shuttle programs will be available for use on the MOSC without a break in their production flow. Multiple use of MOSC test hardware is planned. The scheduling methodology is discussed in more detail in Section 2.

Table 1-3 displays the estimated annual funding distribution by phase. Peak year funding occurs in FY 1983, four years after ATP and one year prior to IOC. The total peak year funding of $236 million is composed of $173 million for DDT&E and $63 million for production.

Table 1-3

BASELINE 4-MAN MOSC

ANNUAL FUNDING DISTRIBUTION
28.5° AND POLAR FACILITIES
(MILLIONS OF FY 1975 DOLLARS)

FY	80	81	82	83	84	85	86	87	88	89	90	Total
DDT&E	9	54	155	173	130	40	10					571
Production	0	0	9	63	95	78	57	12				314
Operations	0	0	0	0	8	67	92	58	33	33	9	300
Total	9	54	164	236	233	185	159	70	33	33	9	1185

To provide a frame of reference for assessing the operational effectiveness of the baseline MOSC system, 230 of the 725 Shuttle flights identified in the 1974 NASA 12-year traffic model (see Book 2) for which stay times in orbit beyond seven days are preferable were used for a comparative evaluation of seven-day Spacelab and extended-duration MOSC operations. These 230 flights involved 42 payloads, all of which are included in the 19 payload groups utilized in the MOSC analysis.

The 230 flights were programmed over an eight-year period in earlier mission models. Therefore, for this comparative purpose only, the program costs for these alternative implementation programs were based upon an eight-year period, 1985 through 1992 (instead of the 1985 through 1989 MOSC operational period used in the rest of this report).

Two hundred and thirty of the seven-day Orbiter-Spacelab/launches/flights would be required to provide approximately 58,000 manhours necessary to accomplish the research objectives of the 42 payloads. By contrast, two MOSC facilities, one in polar orbit and one in a 28.5° inclination orbit, during this same eight-year period would nominally require only 68 support launches (two Shuttle flights to launch each orbital facility plus eight logistics flights each year for eight years). Although this eight-year MOSC program would provide over 77,000 working manhours in orbit, only 38,000 manhours would be required (assuming an 85 percent learning curve) to perform the tasks requiring 58,000 manhours in the 230 flights operating in the sortie mode. These surplus manhours in the MOSC program would be available for other activities and to support additional payloads as they are developed.

Figure 1-9 presents the cumulative operational costs for performing an eight-year program with MOSC and with the Spacelab. Assumptions upon which the comparison was made are (1) identical experiment programs, (2) identical payload costs, (3) Shuttle launch costs at $12.2 million per launch, (4) no development costs for Spacelab due to European support, and (5) MOSC total program costs of the $1,184.6 million baseline plus the additional cost required for the Shuttle launches and to extend the operational period from 1989 to 1992. On the basis of these results, it can be seen that there are significant cost advantages to using the MOSC approach as compared to the other alternative (with an identical experiment program). A continuing and expanded MOSC program, encompassing 68 flights during this same period, would total $2.06 billion as compared to $2.81 billion for the Spacelab.

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	TOTAL LAUNCHES	BILLIONS OF DOLLARS	REMARKS
SPACELAB	230	$2.81	
MOSC	68	2.06	LAUNCH ON 90-DAY CENTERS 2 FACILITIES (POLAR AND 28.5°)

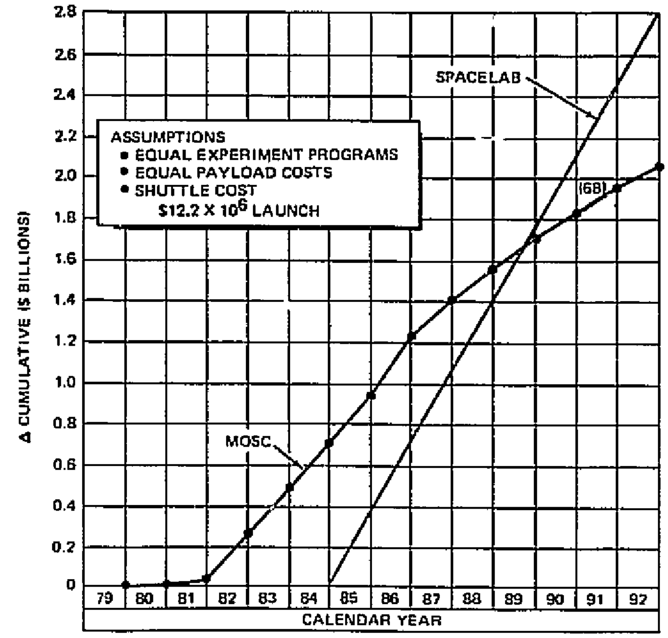


Figure 1-9. Operational Cost Comparisons of MOSC and Spacelab

Section 2
COSTING APPROACH, METHODOLOGY, AND RATIONALE

2.1 INTRODUCTION

This section contains general information which provides a foundation for interpreting and evaluating the data presented in the other sections of the report.

2.2 WORK BREAKDOWN STRUCTURE (WBS)

The NASA-approved WBS is a task-oriented hierarchy for the purpose of systematically identifying the elements of work required to achieve the objectives of the MOSC project and to organize them into logically related levels of activity. It provides a uniform framework (1) for collecting and defining costs and (2) for coordinating the various activities of the program, especially technical analyses, costs, schedules, manpower, logistics, maintenance and refurbishment, and, to a lesser extent, tests, manufacturing, spares, reliability, and safety.

The MOSC WBS (Figures 2-1 and 2-2) is typical of the structure used in previous projects except at Level 4, which is typically designated as the "Systems" level. In the MOSC program it has been found convenient to use a sublevel of 4.5 to identify the four individual modules which combine to form the complete Level 4 integrated module system. The Level 5 subsystems are combined into the four individual modules at Level 4.5, and these modules are then combined into the integrated modules system at Level 4.0. This approach provides visibility for each separate module and still maintains maximum compatibility with the normal WBS definitions for each level. This dual level localizes the impact of the MOSC unique features to Level 4 and does not affect either lower or higher levels. Figure 2-3 identifies, in

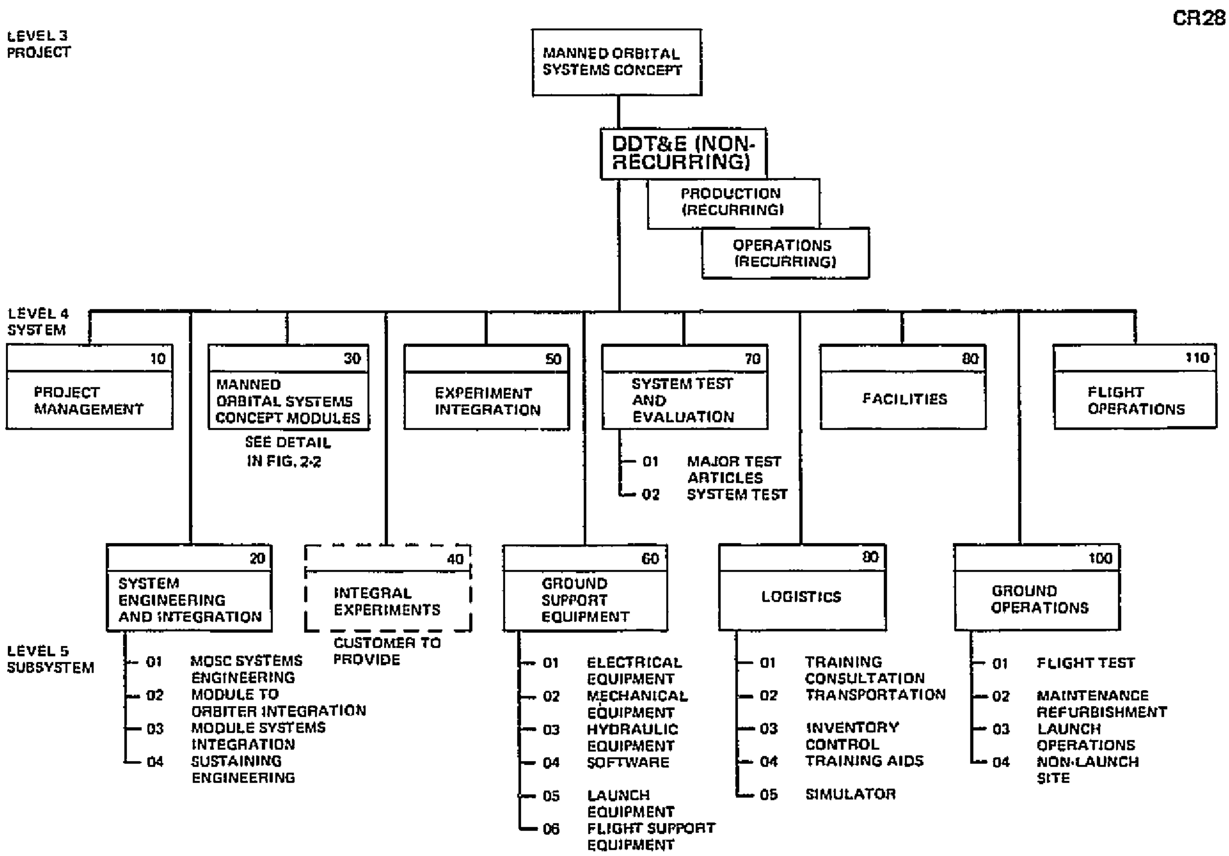


Figure 2-1. MOSC Work Breakdown Structure

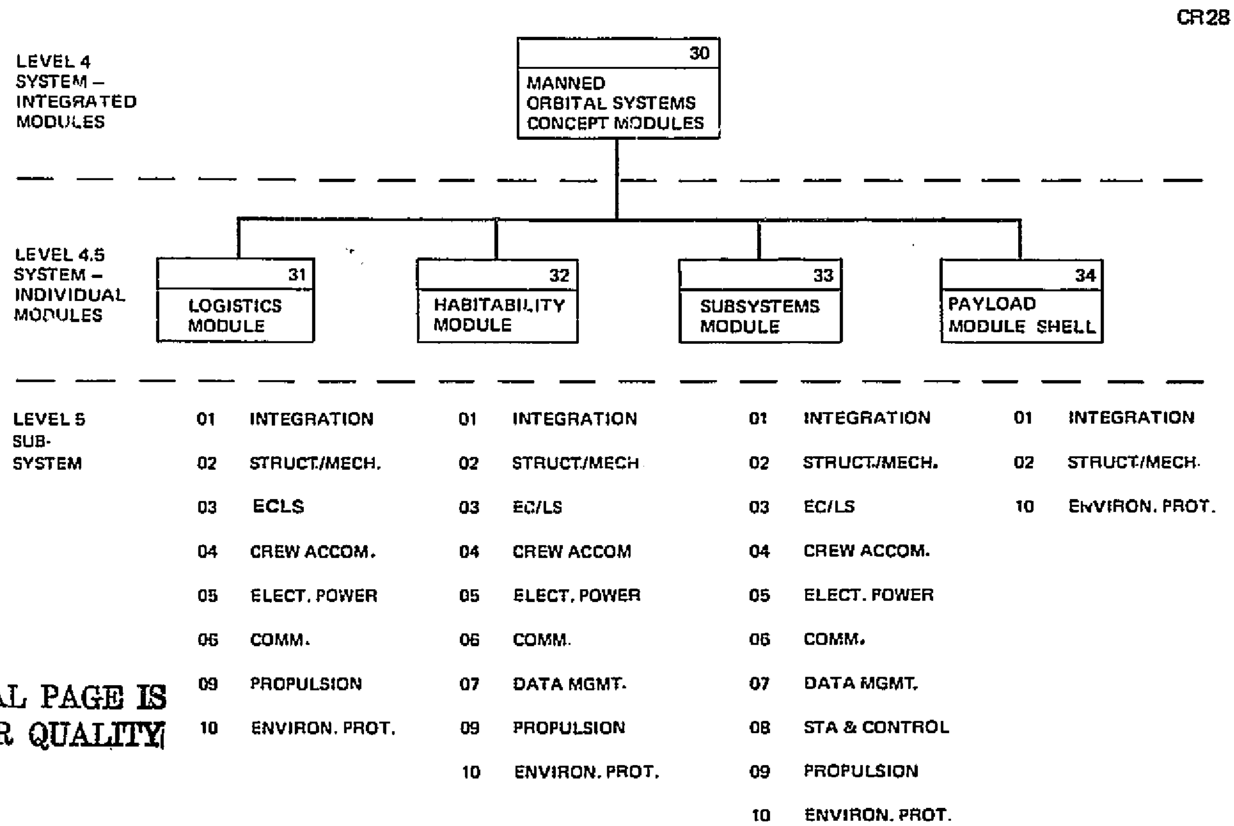


Figure 2-2. Detail of Levels 4.5 and 5 Under WBS 30

WBS NO.	WBS IDENTIFICATION SYSTEM LEVEL ELEMENTS	LOWEST LEVEL OF INFORMATION DOCUMENTED IN THIS REPORT				LEVEL COSTS ACTUALLY ESTIMATED
		WBS DICTIONARY	COST ESTIMATES	SCHEDULE	FUNDING ESTIMATES	
10	PROJECT MANAGEMENT	4	4	4	4	4
20	SE&I	5	5	4	4	5
30	MOSC MODULE	5	5	5	4	6 & 7
40	INTEGRAL EXPERIMENTS	(1)	(1)	(1)	(1)	(1)
50	EXPERIMENT INTEGRATION	(2)	(2)	(2)	(2)	(2)
60	GSE	5	5	4	4	5
70	SYSTEM TEST AND EVALUATION	5	5	4	4	5
80	LOGISTICS	5	5	4	4	5
90	FACILITIES	4	4	4	4	4
100	GROUND OPERATIONS	5	5	4	4	6
110	FLIGHT OPERATIONS	(3)	(3)	(3)	(3)	(3)

(1) EXPERIMENT COSTS NOT INCLUDED BY NASA DIRECTION

(2) EXPERIMENT INTEGRATION VARIES FROM LESS THAN 25 PERCENT TO MORE THAN 100 PERCENT OF THE COST OF THE EXPERIMENT DEPENDING ON THE TYPE OF EXPERIMENT. NEITHER THE EXPERIMENTS NOR THEIR COSTS WERE IDENTIFIED, THEREFORE THEIR INTEGRATION COSTS COULD NOT BE CALCULATED.

(3) ALL FLIGHT OPERATIONS ARE CONDUCTED BY NASA FLIGHT CREWS AND ARE EXCLUDED.

Figure 2-3. Level of Detail for Each WBS Item

terms of WBS level, the depth of detail associated with the cost and schedules analysis for each Level 4 system element in this study.

2.3 COSTING METHODOLOGY

2.3.1 General

The overall costing approach employed in estimating costs for each WBS element by program phase is summarized in Table 2-1. Table 2-2 augments the data in Table 2-1 and identifies whether a direct estimate, costing estimating relationship (CER), or a cost factor was utilized in developing each element of the cost estimate.

Throughout the study, wherever sufficient technical definition was available and adequate cost data could be obtained, a direct estimate was used to predict the cost of each item. Direct estimates of hardware costs were derived from two sources of information. The first source was actual cost history of hardware programs, which includes both MDAC and supplier data. The second source was quotations from hardware vendors who were experienced in supplying the type of hardware being estimated. Privileged historical cost data generated during such hardware programs as Skylab, Saturn SIVB, Gemini, MOL, and Thor/Delta, as well as other vendor data in the MDAC data bank, provided the first source of information. Vendor replies to formal requests for information (RFI) provided the second source of information. These responses were compared with historical data and with each other to ensure the responses were realistic and to minimize the impact of inconsistencies that may have been injected into the quotations. Direct estimates of nonhardware costs were developed primarily from manload estimates based on task evaluations. The breadth and realism of these estimates were augmented by comparisons with data from previous activities such as the Phase B, Space Station Definition* study.

*NASA Phase B Space Station Defintion Study, Contract NAS 8-25140, McDonnell Douglas Astronautics Company, Huntington Beach, California, 1970-72

Table 2-1

OVERALL COST METHODOLOGY

WBS Elements		ESTIMATING TECHNIQUE APPLIED	
WBS NUMBER	WBS INDENTIFICATION		
--	Total MOSC Project	Summation of all lower level values in Systems Level 4	
10	Project Management	Percentages of total Level 4 costs excluding Project Management	
20	Systems Engineering and Integration	Summation of lower level values in Subsystem Level 5 (WBS Series 20)	
2001	MOSC Systems Engineering	DDT&E -	Percentage of sum of DDT&E cost for WBS 30, MOSC - All Modules and WBS 2003 Module-to-Module Integration
		Production -	Computed as a factor of Total Production Cost for WBS 30, MOSC - All Modules and WBS 2003, Module-to-Module Integration.
2002	Module to Orbiter Integration	DDT&E -	Percentage of Total MOSC hardware DDT&E cost (WBS 30 and WBS 2003)
		Production -	Same as 2001
2003	Integration Module-to-Module	DDT&E -	Percentage of WBS 30, MOSC - All Modules DDT&E cost
		Production -	Percentage of WBS 30, MOSC - All Modules production costs
2004	Sustaining Engineering	DDT&E -	NA
		Production -	Computed as a function of module complexity, production schedule, production rate, and Total Production Cost for WBS 30, MOSC - All Modules
		Operations -	Time related level of effort

Table 2-1

OVERALL COST METHODOLOGY

WBS Elements		ESTIMATING TECHNIQUE APPLIED
WBS NUMBER	WBS INDENTIFICATION	
30	MOSC - All Modules (Manned Orbital Systems Concept Modules)	Summation of lower level values in System Level 4.5 (WBS Series 3000)
31	Logistics Module	Summation of lower level values in Subsystem Level 5 (WBS 3100 series)
32	Habitability Module	Summation of lower level values in Subsystem Level 5 (WBS 3200 series)
33	Logistics Module	Summation of lower level values in Subsystem Level 5 (WBS 3300 series)
34	Payload Module Shell	Summation of lower level values in Subsystem Level 5. (WBS 3400 series)
3X01	Integration Assembly and Checkout	Percentage of the sum of all subsystem costs excluding Ingegration Assembly and Checkout of the subsystem's into the system

Table 2-1

OVERALL COST METHODOLOGY

WBS ELEMENT		ESTIMATING TECHNIQUE APPLIED
WBS NUMBER	WBS INDENTIFICATION	
3X02 3X03 3X04 3X05 3X06 3X07 3X08 3X09 3X10	Structure/Mechanical Environmental Control and Life Support Crew Accommodations Electrical Power Communications Data Management Stabilization and Control Propulsion Environmental Protection	DDT&E: ED&D - CER's and direct estimates expressing costs as a function of design, types of material, methods of fabrication, area, weights and types of construction. Each value modified by a factor (varying from 0.1 to 1.0) to reflect the extent that existing hardware is incorporated in the item being designed. GTH - Percentage of the First Unit Cost of each item at the lowest level of estimating. Percentage reflects amount of modification to existing hardware and complexity of the item. Production - CER and direct estimates expressing the cost as a function of design, types of material, quantities, method of fabrication and other considerations. A small complement of initial spares was provided by applying a factor to the production cost. Operations - Spares were calculated as a function of type of subsystem, quantity produced and duration of operational program.
40	Experiment Hardware	Not included
50	Experiment Integration	Not calculated. Dependent on WBS 40, Experiment Hardware
60	Ground Support Equipment	Summation of lower level values in Subsystem Level 5 (WBS series 60)

Table 2-1

OVERALL COST METHODOLOGY

WBS Elements		ESTIMATING TECHNIQUE APPLIED
WBS NUMBER	WBS INDENTIFICATION	
6001 6002 6003 6004 6005 6006	Electrical GSE Mechanical GSE Hydraulic GSE Software Launch Equipment Flight Support	DDT&E - Percentage of DDT&E cost of WBS 30, MOSC - All Modules and WBS 2003, Module-to-Module Integration. Production - Intial Spares. Factor of DDT&E cost of item. Operations - Function of type of subsystem, quantity produced, duration of operational program
70	Systems Test and Evaluation	Summation of lower level values in Subsystem Level 5 (WBS Series 70)
7001	Major Test Articles	Percentage of First Unit Cost of WBS 30, MOSC - All Modules, and WBS 2003, Module-to-Module Integration less percentage of Ground Test Hardware (Components) of WBS 30, MOSC - All Modules
7002	Major Test Operations	Percentage of cost of WBS 7001, Major Test Article before adjusting for hardware available from component development and qualification tests
80	Logistics	Summation of lower level values in Subsystem Level 5 (WBS Series 80)
8001	Training - Consultation	Labor man-years X cost/man-year for technical consultants
8002	Transportation	Cost/trip X number of trips
8003	Inventory Control	Labor man-years X cost/man-year
8004	Training aids	Percentage of Total MOSC Hardware Production Cost - WBS 30, All Modules and WBS 2003, Module-to-Module Integration
8005	Simulator	Percentage of First Unit cost of MOSC hardware modified for amount of GTH and Major Test Hardware available for use in the Simulator.

Table 2-1

OVERALL COST METHODOLOGY

WBS Elements		ESTIMATING TECHNIQUE APPLIED
WBS NUMBER	WBS INDENTIFICATION	
90	Facilities	Percentage of Total MOSC Hardware DDT&E Cost
100	Ground Operations	Summation of lower level values in Subsystem Level 5. (WBS Series 100)
10001	Flight Test	None required
10002	Maintenance/Refurbishment	Labor man years/facility X Number of facilities X Cost/Man-year (Cost of parts and material included in MOSC hardware. WBS 3000 series and GSE, WBS 60 series, production and operations costs.)
10003	Launch Operations	Same as WBS 10002
10004	Non Launch Site Operations	Same as WBS 10002

Table 2-2

COST METHODOLOGY APPLICATION OF CER'S, COST FACTORS AND DIRECT ESTIMATES

WBS IDENTIFICATION NUMBER	WBS INDENTIFICATION	DDT&E			PRODUCTION			OPERATIONS	
		CER'S	COST FACTORS	Direct Est/ Sum**	CER'S	COST FACTORS	Direct Est/ Sum**	COST FACTORS	Direct Est/ Sum**
100-	Total MOSC Project			SUM			SUM		SUM
10	Project Management		X			X		X	
20	System Engineering and Integration			SUM			SUM		SUM
2101	MOSC System Engineering		X			X			
2202	Module-to-Orbiter Integration		X			X			
2303	Module-to-Module Integration		X			X			
2404	Sustaining Engineering				X				DE
30	MOSC - All Modules			SUM			SUM		SUM
31	Logistics Module			SUM			SUM		SUM
32	Habitability Module			SUM			SUM		SUM
33	Subsystems Module			SUM			SUM		SUM
34	Payloac Module-Shell			SUM			SUM		SUM
3X01*	Integration, Assembly, and Checkout		X			X			
3X02*	Structure/Mechanical	X			X			X	
3X03*	Environmental Control and Life Support			DE			DE	X	
3X04*	Crew Accommodations	X		DE	X		DE	X	
3X05*	Electrical Power	X			X			X	
3X06*	Communications			DE			DE	X	
3X07*	Data Management			DE			DE	X	
3X08*	Stabilization and Control			DE			DE	X	
3X09*	Propulsion			DE			DE	X	
3X10*	Environmental Protection	X			X			X	
60	Ground Support Equipment			SUM			SUM		SUM

Table 2-2

COST METHODOLOGY
APPLICATION OF CER'S, COST
FACTORS AND DIRECT ESTIMATES

WBS IDENTIFICATION NUMBER	WBS INDENTIFICATION	DDT&E CER'S	DDT&E COST FACTORS	DDT&E Direct Est/ Sum**	PRODUCTION CER'S	PRODUCTION COST FACTORS	PRODUCTION Direct Est/ Sum**	OPERATIONS COST FACTORS	OPERATIONS Direct Est/ Sum**
6001	Electrical		X					X	
6002	Mechanical		X					X	
6003	Hydraulic		X					X	
6004	Software		X					X	
6005	Launch Equipment		X					X	
6006	Flight Support		X					X	
70	System Test and Evaluation			SUM					
7001	Major Test Articles		X						
7001	Test Labor		X						
80	Logistics								SUM
8001	Training - Consultation								DE
8002	Transportation								DE
8003	Inventory Control								DE
8004	Training Aids							X	
8005	Simulator							X	
90	Facilities		X						
100	Ground Operations								SUM
10001	Flight Test							(None)	
10002	Maintenance and Refurbishment								DE
10003	Launch Operations								DE
10004	Non Launch Site Operations								DE
110	Flight Operations							NASA	

*The 'X' indicates the information applies to any one of the four modules. X=1 or 2 or 3 or 4, and the columns checked indicate the methodology used for the majority of the lower level estimates.
**SUM indicates the WBS item is the sum of lower level items listed in this table. Direct Estimate is abbreviated "DE" in the body of the table.

The second method of estimating costs was through the utilization of "cost estimating relationship(s)" (CER). The CER has the general form: Cost $= A(X)^B$ (factor). CER development and mathematics have been previously documented* and will not be repeated here. During the MOSC study, care was used to ensure that the combination of the basic CER and its factor/modifier realistically reflected the technical, programmatic, and (if a DDT&E phase cost) the extent of modification to existing hardware.

The third type of estimating technique used for the MOSC, and identified in Table 2-2, was the utilization of cost factors. These factors, which were derived from historical data, calculate one cost element as a percentage of another. This method was used for estimating portions of the nonhardware costs such as project management.

Whenever the level of available technical detail was sufficiently definitive, the cost elements were estimated at a lower level of detail then the level documented in this report.

Data from the Phase B Space Station Definition Study also provided convenient, detailed, and complete Phase B hardware lists, which were used as check lists to ensure completeness of coverage in the analyses conducted.

The development cost associated with each item of hardware was divided into two categories. One category included the cost of developing the item itself and the other category included the cost of integrating that item into its higher level assemblies. If an item did not exist, the MOSC program was charged the total cost of the new development of the individual item plus the total cost associated with integrating the individual item into its higher level assembly. If an item existed but required modification to meet MOSC specifications, the charge for its individual development was decreased as a function of the degree of adequacy of the item, but the same integration cost was charged as if the item were a new development. If an item already existed and was used in the MOSC without change, the minimum charged to the MOSC was 10 percent of the cost of its individual development plus the full "new" integration cost. (See illustrative example in Subsection 2.4). The 10 percent basic

*ibid, Paragraph 2.3.1

charge for an existing item was included to cover the estimated cost of such functions as (1) verifying that the specifications of the article do in fact meet the MOSC requirements, (2) verifying that the article has passed adequate qualification tests, and (3) providing the drawings and other documentation associated with using the item. The 10 percent ratio also assumes the item is available from a production line that is active at the time the item is needed in the MOSC program. If this assumption were not true, additional tooling and startup charges would be incurred.

A further consideration in estimating development costs was the utilization of an article in several places. If the same item was used in more than one module, a factor greater than one was applied to the integration cost to account for the multiple usage. (See Subsection 2.4 below for a specific illustration of how these DDT&E factors were used.)

The impact of the test hardware is discussed in Section 5.2, where Level 4 systems costs are presented, and in Section 3.2, where the schedules are discussed.

The MOSC GSE requirements were not defined in this study. On past programs, the GSE has ranged from about 8 percent to 12 percent of the program's development cost. For the MOSC, the GSE was assumed to be at the upper end of the range. In view of the fact that some GSE already available for the Spacelab program could be used, it is believed that this is a conservative estimate.

One exception to the generally conservative approach taken in estimating costs was in the area of sustaining engineering. Many past programs have had a high rate of engineering change order traffic. The MOSC project is ground ruled to be austere. This was reflected by assuming that tight management control would decrease change order traffic by rejecting all change orders except those required to provide an end product that would meet the initial program objectives or those involving safety requirements. This approach was reflected by a significant decrease in the sustaining engineering estimate. (See Sections 2.4.20 and 6.2.)

The MOSC cost methodology has been formulated to provide a realistic, early cost estimate for the project. The conservative nature of the estimates made will tend to minimize potential increases in the cost estimate as the concept progresses from pre-Phase A into the more in-depth studies. It is anticipated that any significant growth in the cost estimate as MOSC progresses into more detailed design stages will be limited to changes that reflect modifications in engineering design, program requirements, inflation, or changes in costs of Spacelab hardware.

2.3.2 MDAC LEADER Costing System

The LEADER* II costing system was used in computing the costing data for the MOSC study. The LEADER II system is a family of computer programs developed by MDAC which constructs a cost model and generates cost estimates in which the output format conforms to the NASA-approved WBS.

Inputs to the LEADER II, Figure 2-4, consist of four basic types of data: (1) hardware characteristics, i.e., size, weight, power, etc.; (2) schedules, i.e., component, equipment, vehicle flight, program milestones; (3) cost evaluation parameters, i.e., CER's, direct estimates, factors, etc.; and (4) NASA-approved WBS. The LEADER II system (1) processes these inputs and (2) outputs both cost and funding estimates. The MOSC life-cycle cost estimate is a tabular output which displays DDT&E, production, operations, and total life-cycle costs for each WBS element at WBS Levels 3, 4, and 5 (see Appendix B).

Additional outputs are formatted as required by Cost Data Forms A(1) DDT&E, A(2) Production, and A(3) Operations. (These data are presented in Appendices C, D, and E, respectively.) The funding distribution resulting from relating costs and schedules may be tabular, as required by NASA Funding Schedule Data Form C, or graphic, annual and cumulative (see Section 7 and Appendix F).

*Life-Cycle Estimates Analytically Derived from Engineering Relationships

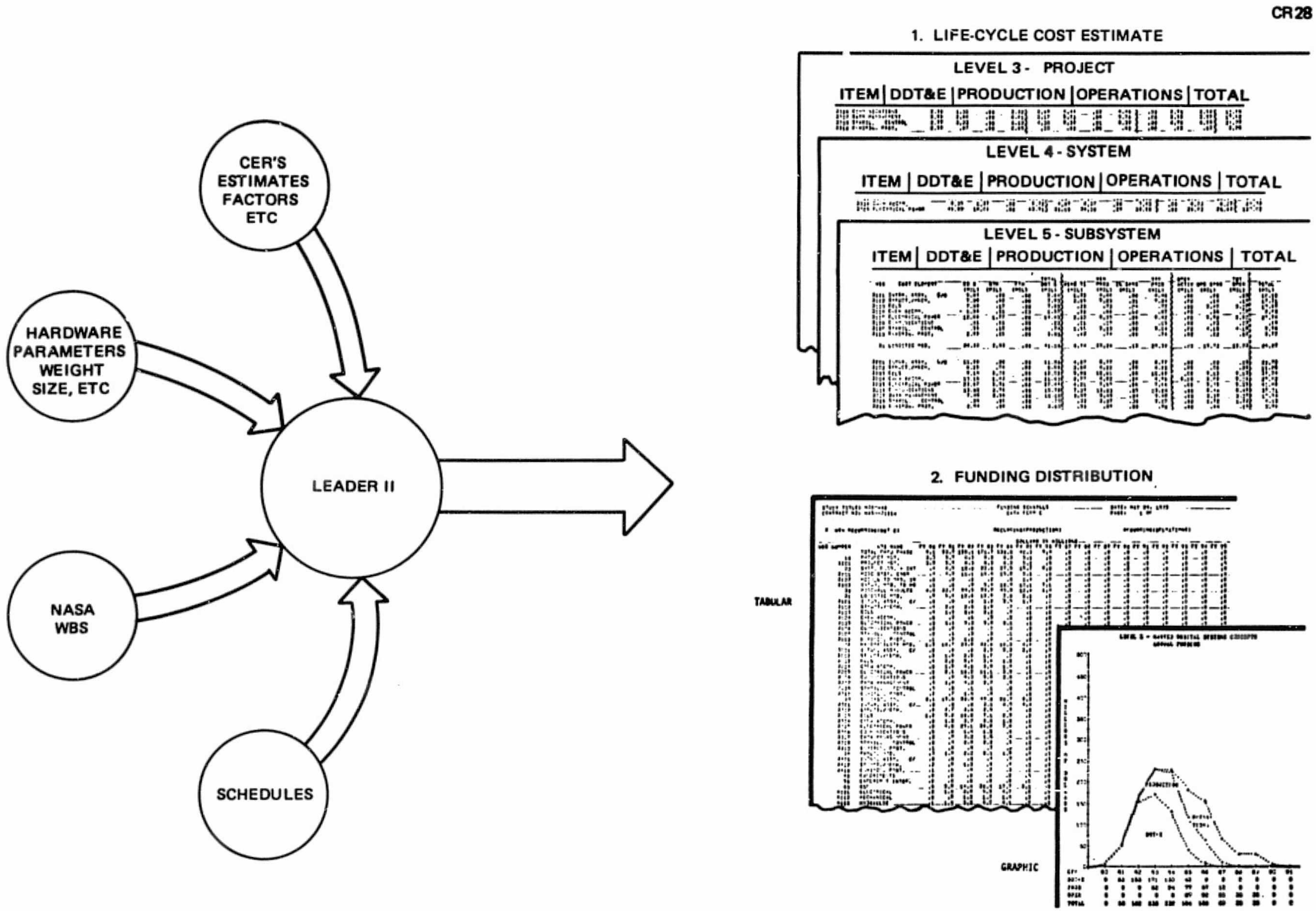


Figure 2-4. LEADER II Costing System

2.4 GROUND RULES AND ASSUMPTIONS

The cost and schedule ground rules and programmatic assumptions utilized in the MOSC study are presented below.

The cost and schedule estimates assumed that the phases C/D ATP will be 1 January 1980, IOC for a 28.5° orbital facility will be December 1984, IOC for a polar facility will be December 1986, and the operational phase for both orbital facilities will extend through December 1989.

The estimates assumed each orbital facility had two logistic modules, one habitability module, one subsystem module, and two payload module shells.

Cost estimates are reported in constant fiscal year, December, 1975 dollars. Funding distribution is in October 1 to September 30 fiscal years.

Cost estimates are commensurate with the program definitions available at the time of the estimate, the relative level of study effort, and with the understanding that the estimates are only for preliminary planning and tradeoff study purposes.

Cost estimates have been developed in consonance with the latest MSFC-approved Work Breakdown Structure and dictionary.

Cost estimates exclude experiment costs by NASA direction and experiment integration costs because they cannot be derived without the costs of the individual experiments.

By NASA direction the cost estimates exclude (1) NASA effort for program management and system support, (2) Shuttle launch and support, and (3) salaries and training of Orbiter and MOSC flight crews. Thus, the estimates exclude the NASA institutional base.

When required for performing tradeoff analyses, Shuttle costs were assumed to be $12.2 million (FY 1975 dollars) per flight.

Project management costs were estimated as 5 percent of total project cost before calculating project management.

DDT&E cost estimates assume that hardware developed for the Spacelab and Orbiter programs is available to the MOSC program wilthout further DDT&E cost except for rework associated with modifications to conform to MOSC requirements.

DDT&E estimates assume that the cost associated with using existing hardware without any modifications will be 10 percent of the new development cost plus the full cost of integrating it into its next assembly plus the cost of one ground test hardware item.

DDT&E cost estimates assume that technology, and testing effort associated with the Skylab's orbital workshop (OWS), Apollo telescope mount (ATM), airlock module (AM), and multiple docking adapter (MDA) are available to the MOSC program at no further cost. However, the estimates reflect that these programs are terminated and new tooling is required. New qualification testing is not required, except to qualify modified designs.

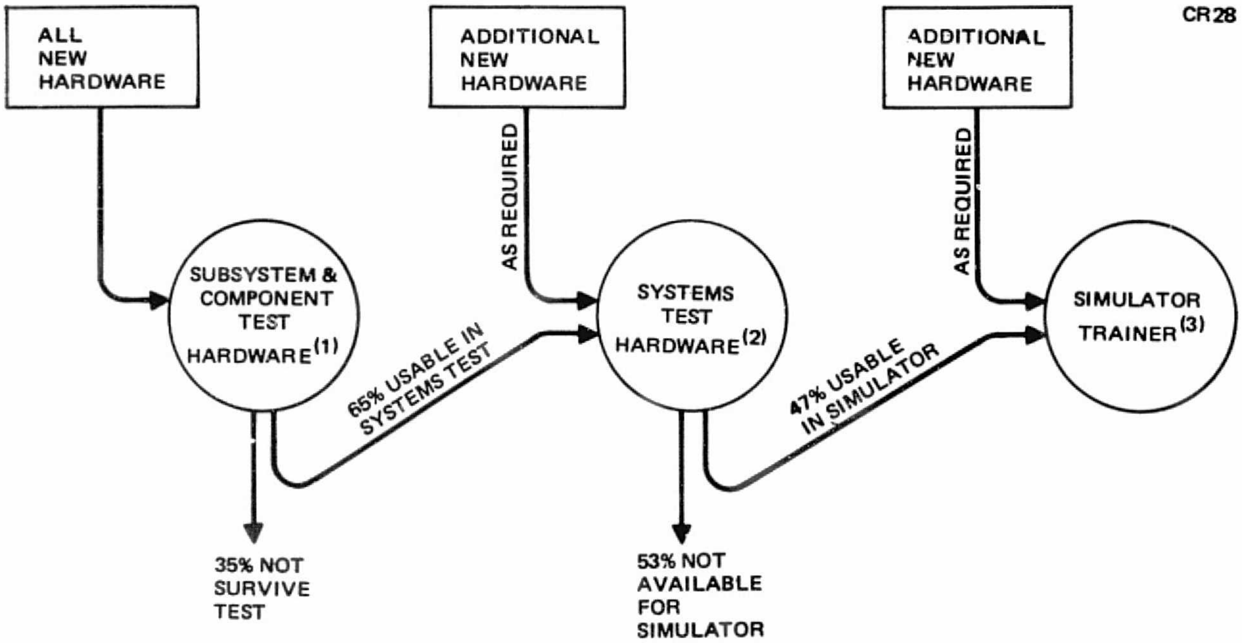
No supporting research and technology (SRT) program is mandatory for the baseline MOSC configuration.

Dedicated flight test hardware is not required.

DDT&E cost estimates assume multiple use of test hardware, Figure 2-5. (See Section 6, Figure 6-1 for the cost results of applying the following test hardware assumptions.) The test hardware cost assumes:

A. The cost equivalent of at least one unit of each hardware item (existing or new development) is required for the partial mockups and development/qualification test at subsystem level and below. (Table 6-15 in Section 6 summarizes the ground test hardware equivalencies actually used.)

B. Sixty-five percent of the development or component test hardware survives the tests and has a second use as systems test hardware or in the simulator.



(1) TOTAL COST EQUIVALENT TO SUM OF COST OF AT LEAST ONE UNIT OF EACH HARDWARE ITEM
(2) TOTAL COST EQUIVALENT TO 0.7 OF HARDWARE COST OF FIRST SET OF MOSC MODULES
(3) TOTAL COST EQUIVALENT TO HARDWARE COST OF FIRST SET OF MOSC MODULES

Figure 2-5. Assumption/Rationale for Multiple Use of Test Hardware

C. The total system test hardware cost before taking credit for surviving GTH is equivalent to 0.7 of the cost of the first set of module hardware.

D. Forty-seven percent of the total cost of the systems test hardware is available for use in the simulator/trainer.

E. The total cost of the simulator/trainer before adjusting for hardware available from systems test is equivalent to the cost of the first set of MOSC module hardware.

The cost estimates assume that all hardware DDT&E and hardware production will be allocated to contractor(s) in a manner that will minimize cost and maximize benefits of commonality.

The cost of ground support equipment was assumed to be 11 percent of development cost. (See rationale discussion in Subsection 2.3.2.)

Production cost estimates assume that flight-qualified units from the Spacelab and Orbiter programs are available for purchase by the MOSC project and that these items will be obtained before their production lines are closed (i. e., no start-up costs will be incurred).

Production cost estimates assume that any existing flight-qualified hardware units from the Skylab OWS, ATM, AM, and MDA would be over-age by the time they would be incorporated into this program. Thus, new units will be produced and normal acceptance tests will be performed for MOSC.

Sustaining Engineering cost calculations resulted in it being estimated as 17 percent of module hardware production cost.

No backup flight articles are required.

Based on the reliability and maintainability analyses performed for the Phase B Space Station Definition Study (contract NAS8-25140), the initial production and five-year operational spares were assumed to be the following decimal equivalent of each subsystem's cost:

	Decimal Equivalent	
Subsystem	Initial	Operations - 5 years
Structural/Mechanical	0.001	0.021
ECLS	0.010	1.450
Crew Accommodations	0.010	0.950
Electrical Power	0.010	1.190
Communications	0.005	1.100
Data Management	0.005	1.050
Stabilization and Control	0.001	1.400
Propulsion	0.001	1.400
Environmental Protection	0.005	0.010

Contractor support of simulator/trainer operations is shown as operations (training) costs. NASA simulator/trainer operations costs are excluded by NASA direction.

Ground operations costs were direct manhour estimates assuming approximately one-third of the required crews would be contractor personnel and two-thirds NASA personnel.

Maintenance and refurbishment labor costs included only the tasks performed on the ground by contractor personnel. Maintenance and refurbishment operations performed in flight will be accomplished by NASA flight crews.

2.5 COST CALCULATION EXAMPLE

The domes (end conics) that are a part of the structural/mechanical subsystem of the habitability module were selected to illustrate how costs are calculated. Another low-level cost element could have been used for the example, but the domes were selected because they illustrate more of the calculation features than most other items.

The following description of the domes is directly relevant to the cost estimating process:

<u>Physical Characteristics</u>

Material	Aluminum
Outside diameter	4.06 meters
Inside diameter	1.6 meters
Depth of cone	0.7 meter
Construction	6-gore segments
Thickness	0.34 and 0.50 cm stepped not tapered
Estimated weight	480 pounds (average of forward and aft)

<u>Program Parameters</u>

Quantity in each habitability module	2
Quantity of habitability modules	2
Number of different modules in which unit is installed	4

The following basic CER's and equations were input into the LEADER II for estimating the dome's cost:

$$\text{Engr.} = 96,188\ (\text{Weight})^{0.500}\ (F_D) \qquad \text{ED\&D} = \text{Engr} + \text{Tool}$$

$$\text{Tool} = 8,025\ (\text{Weight})^{0.766}\ (F_D) \qquad \text{GTH} = T_1\ (F_G)$$

$$\text{DDT\&E} = \text{ED\&D} + \text{GTH} \qquad \text{Prod} = T_1\ (Q_m)^{\text{LCE}}$$

$$T_1\ \text{Set} = 2,806\ (\text{Weight})^{0.766}\ (F_P)\ (Q_S)^{\text{LCE}}$$

where:

Engr	=	Cost of engineering design and test labor.
Tool	=	Cost of tooling design and fabrication.
ED&D	=	Cost of engineering design and development.
GTH	=	Cost of ground test hardware used for tests up to system level tests.
DDT&E	=	Cost of engineering design, development, and test.
T_1 Set	=	Cost of first production ship set.
	=	Cost of first two production domes.
Prod	=	Cost of production units.
F_D	=	A composite factor for development (see discussion below).
F_P	=	A composite factor for production (see discussion below).
F_G	=	Relationship between cost of first production set and cost of ground test hardware.
	=	Equivalent sets of ground test hardware.
LCE	=	Learning curve exponent = 0.848 for domes (90 percent learning curve).
Q	=	Quantity of habitability modules in project.
Q_S	=	Quantity of domes in each habitability module.

The factors F_D and F_P adjust the basic CER to reflect any differences between the items from which the CER was initially derived and the item being estimated. The differences include changes in such characteristics as type of material, method of fabrication, complexity of design, type of construc-

tion, commonality between modules, and whether the item is an existing or new design.

The flow of the domes through the WBS hierarchy can be visualized as follows:

Level 6	WBS 320202	Dome
Level 5	WBS 3202	Structural/Mechanical Subsystem
Level 4.5	WBS 32	Habitability Module
Level 4	WBS 30	MOSC Module
Level 3	WBS 0	MOSC Project

The factors F_P and F_D were adjusted to reflect that (1) the domes exist on the Spacelab, (2) the design detail and fabrication plan call for the domes to be combined into the structural/mechanical subsystem in two steps requiring double integration, and (3) the domes are used on all four modules. The existence of the domes decreases the development to 0.1 of the new development cost, the use on all four modules doubles the cost but it is shared by all four modules, and the integration factor used was 8 percent. Incorporating these values, F_D for the habitability module domes becomes 0.058 and F_P becomes 1.08.

The factor F_G, the equivalent number of test units, becomes 1/(4*2) or 0.125 for the habitability module to share the cost of providing one dome with the other four modules.

Substituting the values into the equations, the results are as follows:

T_1	$= 2806 * 480^{0.776} * 1.08 * 2^{0.848}$		= 617,468	
Engr	$= 96188 * 480^{0.500} * 0.058$	= 122,227		
Tooling	$= 8025 * 480^{0.766} * 0.058$	= 52,687		
ED&D	= 122,227 + 52,687		= 174,914	
GTH	= 617,468 * 0.125		= 77,184	
DDT&E	= 174,914 + 77,184			= 252,008
Prod	$= 617,468 * 2^{0.848}$			= 1,111,443

A skeleton of the LEADER II cost system output is shown below to illustrate how these values fit into the printout.

WBS	Cost	Engineering Design & Develop.	Ground Test Hardware	Total DDT&E	First Unit Cost	Vehicle Production
	- - - - - - - - - - - -	-FY 1975 Dollars in Millions	- - - - - - - - - -			
320201[1]	Integration					
320202[1]	Domes	0.175	0.077	0.252	0.617	1.111
320203[1]	Cylinder					
320204[1]	Hatch, etc.					
3202[2]	Struct/ Mech.	7.280[2]	0.650[2]	7.930[2]	2.850	9.230[2]

[1] These are synthetic WBS numbers used to illustrate levels and summation procedure.

[2] These values are shown in the printout in Appendix B.

Section 3

BASELINE 4-MAN MOSC SCHEDULES

3.1 SCHEDULE METHODOLOGY

Two activity schedules were constructed for the MOSC. The project schedule defines the milestones associated with the major segments of the project as it progresses from ATP through its development, production, and operations phases. The second schedule shows the timelines associated with each subsystem as it progresses through DDT&E and production phases. The operations phase is not a part of this second schedule since the subsystems are combined into the MOSC modules and lose their identity during the latter part of the production phase.

The schedules were derived by the iterative analysis of the time, risk, and cost impacts of such program requirements and considerations as: design, development, test and evaluation, manufacturing plans and procedures, production rate, quality assurance, safety, maintenance and refurbishment, operations flight schedule, fleet size, and interfaces with other programs. The MOSC schedules were further based on the requirement for nominal IOC (initial operational capability) by 31 December 1984. The production schedule was based on a continuous buildup from lower level assemblies through completed modules for both the 28.5° and polar orbiting facilities.

3.2 PROJECT SCHEDULE

The schedule for the MOSC project conforming to the ground rules listed in Section 2 is shown in Figure 3-1. This schedule covers the design, development, and operations activities, and the facilities required to design, test, produce, and operate the MOSC project systems. Table 3-1 defines the symbols and abbreviations used in Figure 3-1.

The design/development phase authority to proceed (ATP) for the MOSC modules is 1 January 1980. This provides five years for Phase C/D Design and Development, which prior program experience has shown to be a cost-effective schedule for a program of the level of sophistication of that described herein. Completion of the MOSC preliminary design review (PDR) is

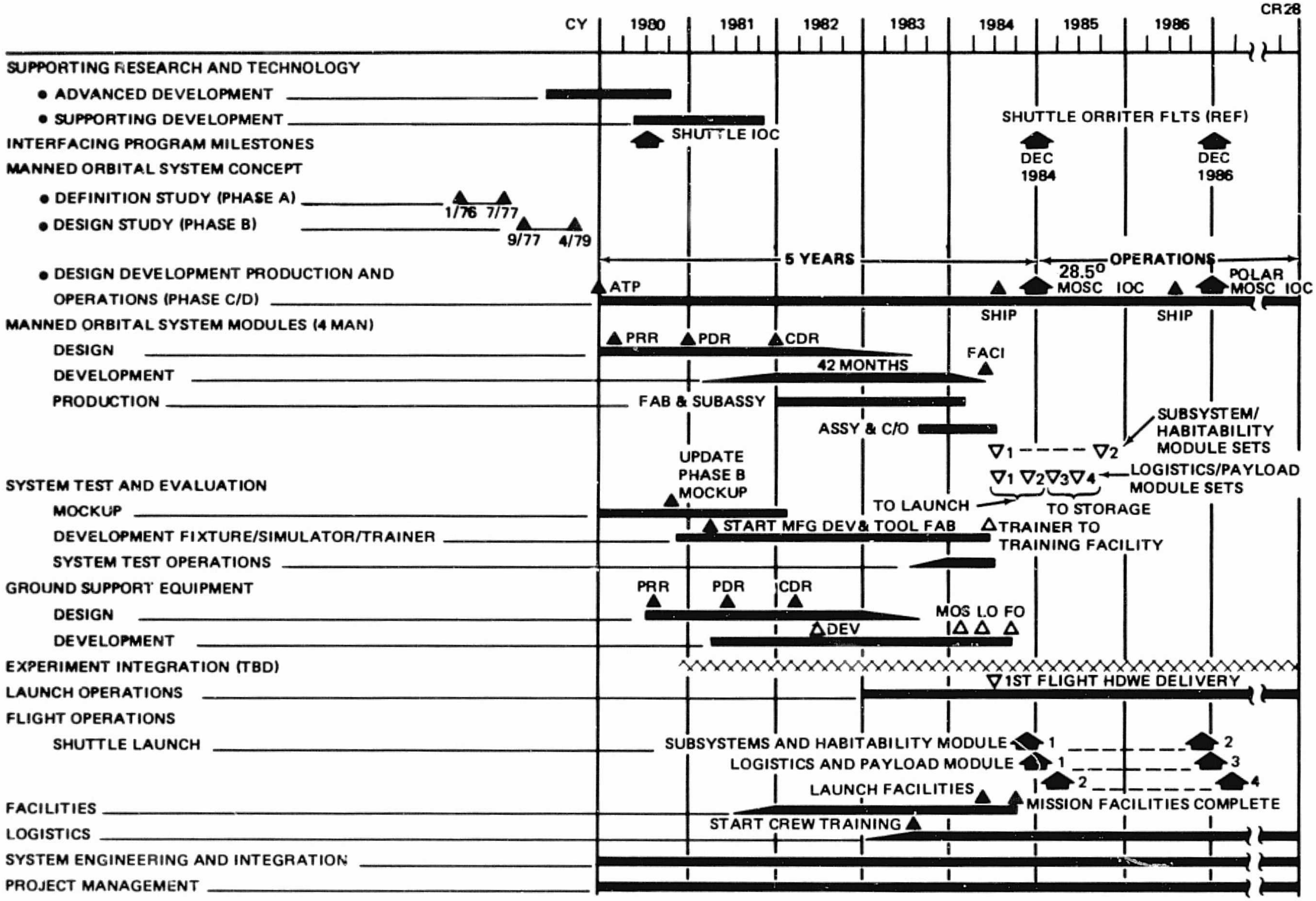


Figure 3-1. Manned Orbital Systems Concepts Project Schedule (4 Man Baseline)

Table 3-1

SCHEDULE LEGEND AND ABBREVIATIONS

	- Spacecraft Operational Launch	FACI	- First Article Configuration Inspection
▲	- Milestone Event	FO	- Flight Operations
△	- Shipment and Delivery	FRR	- Flight Readiness Review
ATP	- Authority to Proceed	LO	- Launch Operations
CDR	- Critical Design Review	MOS	- Manned Orbital System
C/O	- Checkout	MSK	- Major Subcontractor
DT	- Development Test	QT	- Qualification Test
ER	- Engineering Release	PDR	- Preliminary Design Review
FAB	- Fabrication	PRR	- Preliminary Requirements Review
		XXXX	- To Be Determined (TBD)

scheduled for January 1981, twelve months after ATP. This review establishes the module and subsystem configuration for detail design. The critical design review (CDR) will be completed January 1982 and will ensure that the design requirements have been met to this point in time.

Subsystem level test articles required for the development phase will include development fixtures and subsystem development test articles. The development test articles will be used for some interface verification activities and subsystem performance testing. Development fixtures (partial mockups) are relatively inexpensive development tools which prove invaluable in early verification of many design facets. The initial use of the development fixture will be to provide a check of the physical compatibility of subsystem design. Nonoperational subsystems are used for manufacturing development and tool

fabrication. Six months prior to the completion of tool fabrication, flight-equivalent subsystems from development and qualification test are utilized to begin upgrading the development fixtures to the simulator/trainer configuration. From this point forward and prior to MOSC launch, the simulator/trainer activities include the people, procedures, facilities, and production equipment used to verify development functional completion of the MOSC both at the factory and at the launch site. Following manufacturing and checkout at the factory the simulator/trainer is shipped to the launch/training facility for integration, checkout, training, and mission planning.

A continuous low rate production schedule was selected to avoid requirements for rate tooling, multi-shift operation, or interruption/restart costs. Two sets of modules — 2 logistics, 1 habitability, 1 subsystems, and 2 payload shells for each set — will be produced at approximately one module each four months. The second set of modules will be stored until required for the MOSC polar orbit launch in December 1986. Continuous production was selected because experience has shown it to be more cost effective than a production plan featuring interruption and restart.

Storage and removal from storage of those modules required for the polar facility incur relatively modest costs. However stopping, dismantling, and restarting the production line would incur such costs as reinstallation and checkout of tooling, locating and requalifying at least some new sources for hardware items, recruiting and retraining personnel, and perhaps repeating qualification tests for some of the hardware items.

Operations begin with the MOSC/Shuttle launch, which delivers the subsystem and habitability modules to the planned 28.5° inclination orbit. Fifteen days later the logistics and payload modules are carried into orbit by the Shuttle and docked in sequence to complete the initial MOSC. The crew is transferred from the Shuttle to the MOSC and IOC is achieved late in December 1984. This operational sequence is repeated in 1986 for the polar orbit MOSC.

3.3 SUBSYSTEM SCHEDULE

Each of the subsystem schedules in Figure 3-2 include design, development, test, and manufacturing requirements. The MOSC module subsystem level activities presented include design engineering; subsystem development test, qualification test, and deliveries; and operational vehicle manufacturing requirements.

The composite subsystem development and qualification test time spans are based on and compatible with the MOSC module system level time requirements established by the program phase durations. The individual subsystem development and qualification testing is performed during the test time spans shown in Figure 3-2. Schedule estimates were developed at the subassembly and component levels and were based on the technical definitions, quantities, and location of the subsystem in the individual modules. The development and test times established reflect nominal program risk and time spans.

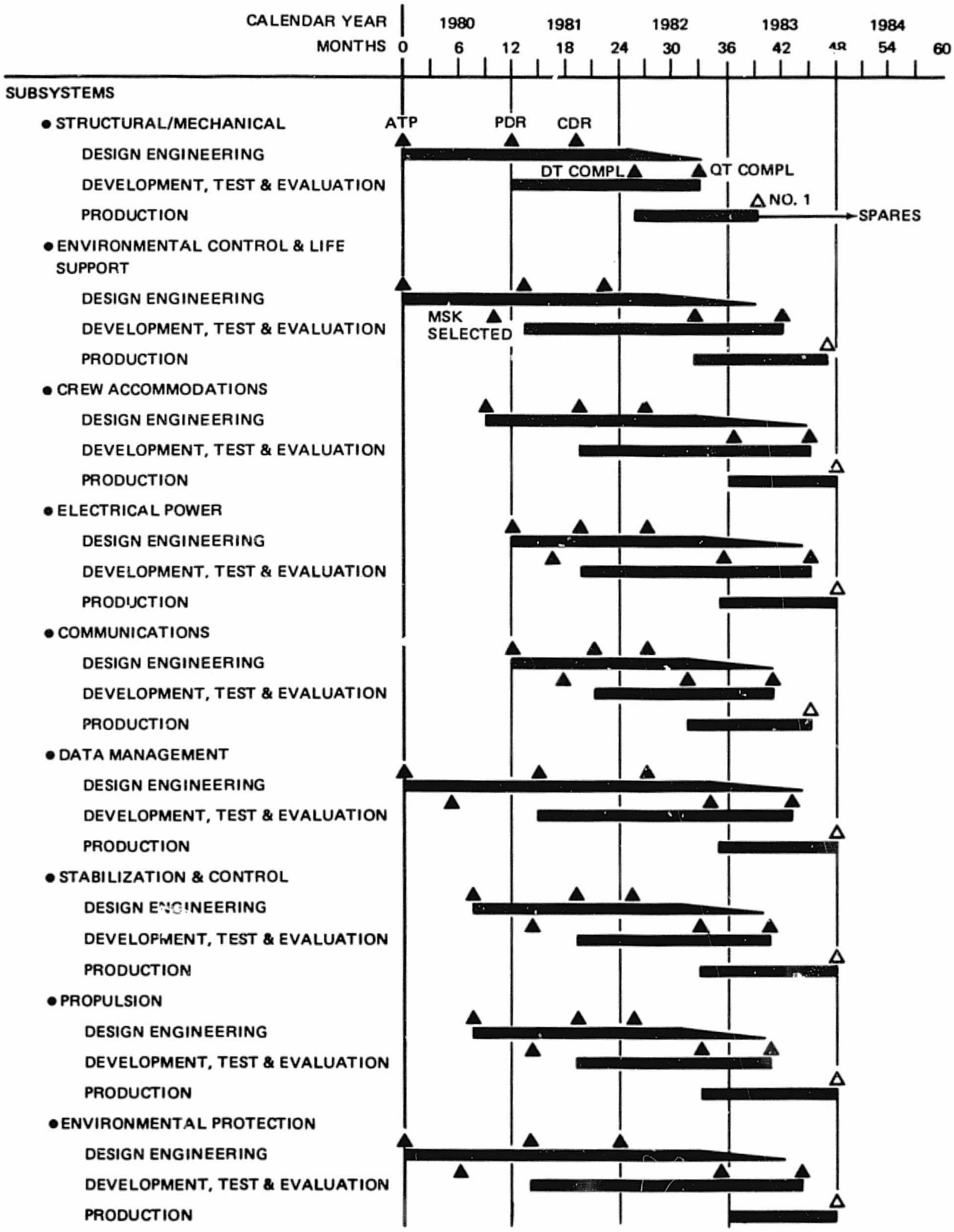


Figure 3-2. MOSC Subsystem Schedules

Section 4
WBS LEVEL 3 — PROJECT COSTS

The MOSC project level cost, defined in Section 2.4 and Appendix A, is the sum of all the MOSC costs documented in this report. The project cost was obtained by summing the costs of the following system level elements:

WBS No.	System
10	Project Management
20	Systems Engineering and Integration
30	MOSC Modules
40	Experiments
50	Experiment Integration
60	Ground Support Equipment
70	System Test
80	Logistics
90	Facilities
100	Ground Operations
110	Flight Operations (NASA)

Based on the ground rules and assumptions presented in Section 2 and conforming to the schedule presented in Section 3, the project cost for developing, producing, and operating two baseline 4-man MOSC facilities is estimated to be $1,184.6 million. This cost is divided as follows: $571.4 million or 48.2 percent is for DDT&E; $313.6 million or 26.5 percent is for production, and $299.6 million or 25.3 percent is for operations. Table 4-1 lists these values and those for the system level elements which comprise the project level totals, while Figure 4-1 presents the data in graphic form for visual comparison of constituent values. Figure 4-2 shows the relative values for the system level elements in each phase — DDT&E, production, and operations.

Details of the system level cost estimates are presented in Section 5.

Table 4-1

TOTAL COST — BASELINE 4-MAN MOSC CONFIGURATION

FY 1975 Dollars in Millions

WBS No.	Description	Phase DDT&E	Prod.	Opers.	Total Project	Percent
10	Project Management	33.3	14.9	14.0	62.2	5.2
20	Systems Eng'r. & Integ.	94.2	100.6	8.0	202.8	17.1
30	MOSC Modules	293.9	197.8	112.4	604.1	51.0
40	Experiments	-	-	-	-	-
50	Expmt. Integration	-	-	-	-	-
60	Ground Suppt. Equip.	62.0	0.3	12.3	74.6	6.3
70	System Test	83.7	-	-	83.7	7.1
80	Logistics	-	-	111.1	111.1	9.4
90	Facilities	4.3	-	-	4.3	0.4
100	Ground Operations	-	-	41.8	41.8	3.5
110	Flight Operations (NASA)	-	-	-	-	-
	TOTAL	571.4	313.6	299.6	1184.6	100.0
		(48.2%)	(26.5%)	(25.3%)	(100.0%)	

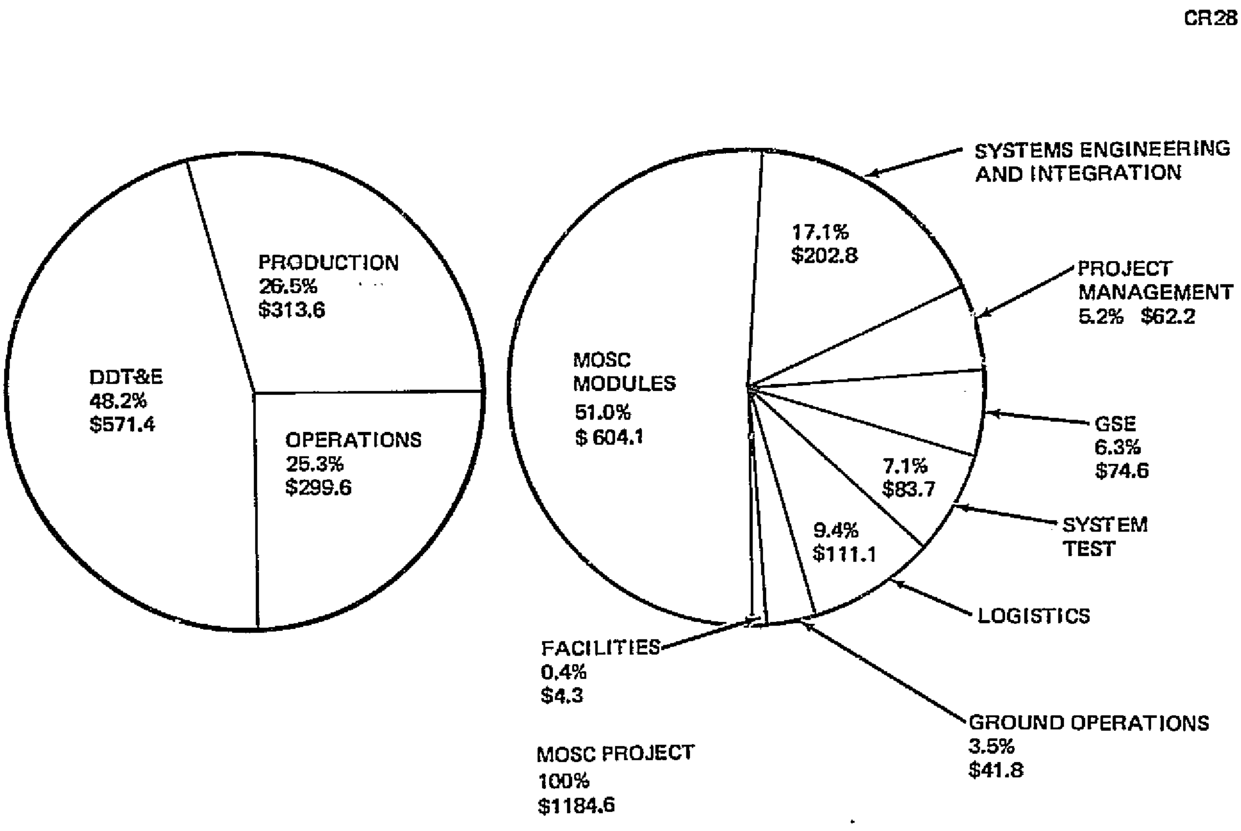


Figure 4-1. Project Cost, MOSC 4-Man Baseline Configuration, 28.5° and Polar Facilities (Millions of FY 1975 Dollars)

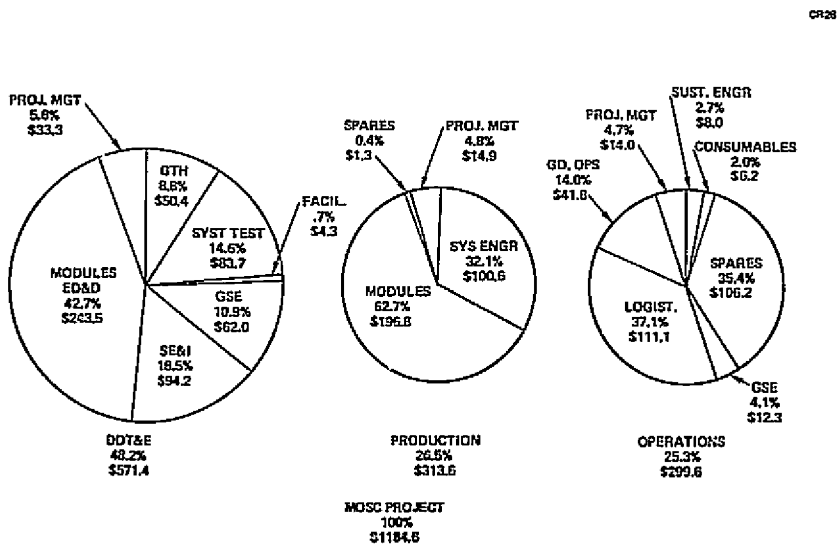


Figure 4-2. Project Costs by System by Phase MOSC Four—Man Baseline Configuration, 28.5° and Polar Facilities (Millions of FY 1975 Dollars)

Section 5
WBS LEVEL 4 SYSTEM COST

This section presents the cost of the various systems and functions required to develop and support the MOSC project. As defined in Section 2.4 and Appendix A, the system level costs are the first major subdivision of costs immediately below the total (project) level cost. They are identified as follows:

WBS No.	System
10	Project Management
20	Systems Engineering and Integration
30	MOSC Modules
40	Experiments
50	Experiment Integration
60	Ground Support Equipment
70	System Test
80	Logistics
90	Facilities
100	Ground Operations
110	Flight Operations (NASA)

The details of the costs that are summed into each of these system level costs are presented in the subsystem cost discussion, Section 6.

5.1 DDT&E PHASE

The DDT&E costs for each system level element (defined in Appendix A) is presented in Table 5-1. This table identifies, by dollar value and percentage of total development cost, the engineering and ground test hardware portion of each system level element. The engineering for the module hardware is the largest part of the $571.4 million estimated as the MOSC project development cost. It accounts for $243.5 million or 42.6 percent of the total. The

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Table 5-1
LEVEL 4 SYSTEM COST
DDT&E PHASE

WBS No.	Description	Engineering Design and Development 10^6$	%	Ground Test Hardware 10^6$	%	Total 10^6$	%
10	Project Management	26.6	4.6	6.7	1.2	33.3	5.8
20	Systems Engineering and Integration	94.2	16.5			94.2	16.5
30	MOSC Modules	243.5	42.6	50.4	8.8	293.9	51.4
40	Experiments						
50	Experiment Integration						
60	Ground Support Equipment	62.0	10.9			62.0	10.9
70	System Test			83.7	14.6	83.7	14.6
80	Logistics						
90	Facilities	4.3	0.8			4.3	0.8
100	Ground Operations						
110	Flight Operations (NASA)						
	TOTAL	430.6	75.4	140.8	24.6	571.4	100%

second largest contributor to the development cost is the hardware for subsystem and system tests. The test hardware for subsystem and component development and qualification tests and some of the mockups, identified in WBS 30, accounts for \$50.4 million or 8.8 percent of the total development cost. Since approximately 75 percent of the hardware used in the MOSC is existing hardware, this value is believed to be a conservative estimate. The items surviving the subsystems test will be utilized in selected systems tests. The remaining system tests will be performed on the first flight unit. The additional hardware required to provide the necessary systems test items and the labor to perform the systems test are estimated to be \$83.7 million or 14.6 percent of the total development cost. The total estimate for the test hardware including its allocation of project management costs (5 percent) account for \$140.6 million or 24.6 percent of the development test. Addi-

tional detail for the test hardware costs, including a diagram of the flow from development tests to simulator/trainer, is presented in Section 6.2 - System Test and Evaluation. (Also see Figure 2-6 in Ground Rules and discussion in Section 3-2.)

The third largest item of the development cost is the systems engineering and integration. The costs associated with this item are further identified in the discussion of subsystems costs in Section 6.2. The development costs estimated for the four, Level 4.5, individual modules which sum into the WBS 30, Level 4, MOSC integrated modules are presented in Table 5-2. The cost of each item of ground test hardware was divided equally among those modules using the hardware item. The ground test hardware accounted for 17.2 percent of the module's hardware development cost.

5.2 PRODUCTION PHASE

The production cost estimates for each system level element is presented in Table 5-3. This table identifies, by dollar value and percentage of total development cost, the production and initial spares portion of each system level element.

Table 5-2

LEVEL 4.5 SYSTEM COSTS*

DDT&E PHASE

WBS No.	Module	Engineering Design and Development 10^6\$	%	Ground Test Hardware 10^6\$	%	Total 10^6\$	%
31	Logistics	38.3	13.0	2.8	1.0	41.1	14.0
32	Habitability	84.9	28.9	14.9	5.1	99.8	34.0
33	Subsystems	112.4	38.2	32.3	11.0	144.7	49.2
34	Payload Shell	7.9	2.7	0.4	0.1	8.3	2.8
30	MOSC Modules	243.5	82.8	50.4	17.2	293.9	100.0

*Costs prorated between modules and based on all modules being developed in same program. Costs shown for individual modules are not representative of the cost that would be incurred if that module were developed separately.

Table 5-3

LEVEL 4 SYSTEM COST

PRODUCTION PHASE

WBS No.	Description	Vehicle Production 10^6\$	%	Initial Spares 10^6\$	%	Total 10^6\$	%
10	Project Management	14.9	4.7	0.0	0	14.9	4.7
20	Systems Engineering and Integration	100.6	32.1	-	-	100.6	32.1
30	MOSC Modules	196.8	62.8	1.0	0.3	197.8	63.1
40	Experiments	-	-	-	-	-	-
50	Experiment Integration	-	-	-	-	-	-
60	Ground Support Equipment			0.3	0.1	0.3	0.1
70	System Test	-	-	-	-	-	-
80	Logistics	-	-	-	-	-	-
90	Facilities	-	-	-	-	-	-
100	Ground Operations	-	-	-	-	-	-
110	Flight Operations (NASA)	-	-	-	-	-	-
	TOTAL COST	312.3	99.6	1.3	0.4	313.6	100.0

The fabrication of the four different modules' hardware accounts for \$196.8 million or 62.8 percent of the total production phase cost of \$313.6 million. The second largest portion of the production cost is \$100.6 million or 32.1 percent estimated as the cost of the systems engineering and integration. As identified in Section 6.2, this includes integrating and assembling the individual modules (Level 4.5) into the total integrated MOSC modules (Level 4).

The initial spares account for \$1.3 million or 0.4 percent of the production phase cost.

The production phase costs for each of the four individual modules (Level 4.5) which sum into the WBS 30, Level 4, MOSC modules are presented in Table 5-4. The subsystem module, WBS 33, accounts for slightly over half

Table 5-4

LEVEL 4.5 SYSTEM COSTS*

PRODUCTION PHASE*

WBS No.	Module	Modules Produced	Vehicle Production 10^6 $	%	Initial Spares 10^6 $	%	Total Hardware 10^6 $	%
31	Logistics	4	29.3	14.8	0.1	0.1	29.4	14.9
32	Habitability	2	57.5	29.0	0.3	0.2	57.8	29.2
33	Subsystems	2	100.7	50.9	0.6	0.3	101.3	51.2
34	Payload Shell	4	9.3	4.7	0.0	0.0	9.3	4.7
30	MOSC Modules		196.8	99.4	1.0	0.6	197.8	100.0

*Assume 4 LM, 2HM, 2SM, and 4PM are produced.

the hardware cost of each facility set, the habitability module for almost three-tenths– with the logistic module and payload module shells accounting for the remaining two-tenths. Table 5-5 presents the total average production cost including pro rata portion of integration and project management for each module and for each facility set.

Table 5-5

TOTAL AVERAGE PRODUCTION COST*

Module	Each Unit 10^6 $	No. Per Set	Each Set of MOSC Modules 10^6 $	%
Logistics	11.7	2	23.4	14.9
Habitability	45.8	1	45.8	29.2
Subsystems	80.2	1	80.2	51.2
Payload Shell	3.7	2	7.4	4.7
MOSC Modules Facility Set =			156.8	100.0

*Assume 4LM, 2HM, 2SM and 4 PM are produced

5.3 OPERATIONS PHASE

The operations cost for each system level element is presented in Table 5-6. This table identifies by dollar value and percentage of total operations cost the operational activity and operational spares required for each system level element.

The operational activity accounts for $175.4 million or 58.6 percent of the $299.6 million cost for the five-year duration of the operational phase. Systems engineering and integration accounts for $8 million or 2.6 percent of the operations cost. This provides $1.6 million ($8.0 divided by five years) per operational year for about a 20-man sustaining engineering staff. This staff is in addition to the larger sustaining engineering staff charged to the

Table 5-6
LEVEL 4 SYSTEM COST
OPERATIONAL PHASE

WBS No.	Description	Operational Activity 10^6 $	%	Operational Spares 10^6 $	%	Total 10^6 $	%
10	Project Management	8.2	2.8	5.7	1.9	14.0	4.7
20	Systems Engineering and Integration	8.0	2.6	-	-	8.0	2.6
30	MOSC Modules	6.2	2.1	106.2	35.4	112.4	37.5
40	Experiments	-	-	-	-	-	-
50	Experiment Integration	-	-	-	-	-	-
60	Ground Support Equipment	-	-	12.3	4.1	12.3	4.1
70	System Test	-	-	-	-	-	-
80	Logistics	111.1	37.1	-	-	111.1	37.1
90	Facilities	-	-	-	-	-	-
100	Ground Operations	41.8	14.0	-	-	41.8	14.0
110	Flight Operations (NASA)	-	-	-	-	-	-
	TOTAL COST	175.4	58.6	124.2	41.4	299.6	100.0

production phase. The $6.2 million or 2.1 percent of the operational cost charged to the MOSC modules is the estimate of the cost of expendables (food, water, gases, propellant, and supplies) delivered to the orbiting facility each 90 days. It includes five years of supplies for the 28.5° facility and three years of supplies for the polar facility.

The largest line item in the operational phase is the $112.4 million for MOSC modules. However, this includes both the operational activity and the operational spares. The largest single item is the operational activity of $111.1 million charged to logistics. A breakdown of the lower level items (Level 5 - Subsystems) that sum into this element is presented in Section 6.6.

The $8.3 million or 2.8 percent and the $5.7 million or 1.9 percent shown for the project management are 5 percent of the sum of operational activity and operational spares, respectively.

The other system level items named in Table 5-6 are discussed in the subsystem level items portion of Section 6.

The operations cost associated with each module is presented in Table 5-7. All the supplies are charged to the habitability module since this contains the crew living quarters. The spares are charged by subsystem to each module.

Table 5-7
LEVEL 4.5 SYSTEM COSTS
OPERATIONAL PHASE

WBS No.	Module	Operational Activity 10^6 $	%	Operational Spares 10^6 $	%	Total 10^6 $	%
31	Logistics	-	-	15.7	14.0	15.7	14.0
32	Habitability	6.2	5.5	31.1	27.7	37.3	33.2
33	Subsystems	-		59.2	52.7	59.2	52.7
34	Payload Shell			0.2	0.1	0.2	0.1
30	MOSC Modules	6.2	5.5	106.2	94.5	112.4	100.0

Section 6
WBS LEVEL 5 SUBSYSTEM COST

This section contains the detail of the subsystem costs, which are summed into the Level 4 system costs. The systems which have subordinate details and are discussed in this section are:

WBS No.	System Name	Paragraph
20	Systems Engineering and Integration	6.2
31	Logistics Module	6.3
32	Habitability Module	6.3
33	Subsystem Module	6.3
34	Payload Module Shell	6.3
60	Ground Support Equipment	6.4
70	Systems Test and Evaluation	6.5
80	Logistics	6.6
100	Ground Operations	6.7

6.1 SYSTEMS ENGINEERING AND INTEGRATION

The SE&I cost estimate, Table 6-1, was divided into four items at Level 5. The sustaining engineering for the production phase provides for an average engineering staff of about 125 men during the production phase activity. This staff will be phased down and after the IOC of the polar facility will be merged into the engineering staff charged to the operational phase.

Table 6-1

WBS 20 — SYSTEM ENGINEERING AND INTEGRATION

FY 1975 DOLLARS IN MILLIONS

WBS No.	Description	Phase Costs DDT&E	Prod.	Oper.	Total Project Cost	Percent
2001	MOSC System Engr.	53.35	14.42	-	67.77	33.4
2002	Module to Orbiter Integr.	3.34	3.62	-	6.96	3.4
2003	Integr. Module to Module	37.54	49.20	-	86.75	42.8
2004	Sustaining Engr.	-	33.39	7.96	41.36	20.4
20	TOTAL	94.24	100.63	7.96	202.84	100.0
		(46.5%)	(49.6%)	(3.9%)	(100%)	

6.2 BASELINE 4-MAN MODULE SUBSYSTEMS

Each of the four modules included in System Level 4.5 is divided into several subsystems as shown below. The tabulation also indicates which subsystems are present in each module.

Level 5 WBS No.	Description	Module Logistics -31-	Habitability -32-	Subsystems -33-	Payload Shell -34-
-01	Integr. Assy. & C/O	X	X	X	X
-02	Struct. /Mech.	X	X	X	X
-03	EC/LS	X	X	X	
-04	Crew Accommodations	X	X	X	
-05	Electric Power	X	X	X	
-06	Communications	X	X	X	
-07	Data Management		X	X	
-08	Stabil. & Control			X	
-09	Propulsion	X	X	X	
-10	Environ. Protection	X	X	X	X

The items included in the cost of each subsystem for each module are tabulated in Tables 6-2 through 6-10. Subsystem costs themselves are tabulated by phase and as a percent of phase total in Table 6-11. The percentages reflect carryover from Spacelab, Orbiter, and Skylab programs. For example, the DDT&E percentages for such subsystems as ECLS, communications, data management, and stabilization/control would be higher than shown in Table 6-11 if these subsystems had to be newly developed. Similarly, total DDT&E cost is shown as 48.7 percent of the total. This percentage would be from 55 to 60 percent for a program requiring a normal amount of new development.

Table 6-2

TABULATION OF ITEMS IN STRUCTURAL/ MECHANICAL SUBSYSTEM

	Distribution of Items			
	Module			
Item	Logistics WBS 3102	Habitability WBS 3202	Subsystems WBS 3302	Payload Shell WBS 3402
Domes (Cones)	1	2	2	2
Cylindrical Section	1	2	1	2
Floor Section	1	2	1	2
Racks Section	1	2	1	-
Bulkhead, Airlock	-	1	-	-
Hatch	2	4	3	2
Hatch Adapter	2	3	3	2
Tunnel	1	-	1	-
Turret	-	-	1	-
Turret Drive	-	-	3	-
Fittings, Set of 3	1	1	1	1
Docking Adapter	2	1	1	2

Table 6-3 (Page 1 of 2)

TABULATION OF ITEMS IN ENVIRONMENTAL AND LIFE SUPPORT SUBSYSTEM

	Distribution of Items			
		Module		
Item	Logistics WBS 3102	Habitability WBS 3202	Subsystems WBS 3302	Payload Shell WBS 3402
O_2 and N_2 Storage	5	-	-	None Included in Estimate
Repressurization Air Storage	-	-	1	
O_2 Pressure Regulation	1	-	-	
N_2 Pressure Regulation	1	-	1	
Atmosphere Pressure Control	-	-	1	
Cabin Dump and Relief	1	1	1	
Airlock Pressure Controls	-	1	-	
PLSS Recharge	1	-	-	
Cabin Fans	-	1	1	
CO_2 Control	1	-	-	
Humidity and Temperature Control	-	1	1	
Water Separation	1	-	-	
Distribution Ducts and Valves	-	1	1	
Contamination Monitoring	-	-	1	
Catalytic Burner	-	-	1	
Avionics Fans	-	1	1	
Avionics Heat Exchanger	-	1	1	
Radiation Circulation	-	-	2	
Interloop Heat Exchanger	-	-	2	
Thermal Capacitors	-	-	16	
Regen. Heat Exchanger	-	-	2	
Cold Plates	-	2	14	
Coolant Water Circulation	-	-	1	
Water Recovery	-	-	2	
Water Dispenser	-	1	-	

Table 6-3 (Page 2 of 2)

TABULATION OF ITEMS IN ENVIRONMENTAL AND LIFE SUPPORT SYSTEM

	Distribution of Items			
		Module		
Item	Logistics WBS 3102	Habitability WBS 3202	Subsystems WBS 3302	Payload Shell WBS 3402
Fire and Smoke Detection	-	1	1	
Fire Suppression	-	1	1	
Crew Prebreathing	-	4	-	
Portable Life Support	-	4	-	
Emergency Pallets	-	1	1	

Table 6-4 (Page 1 of 2)

TABULATION OF ITEMS IN CREW ACCOMMODATIONS SUBSYSTEM

Item	Distribution of Items		
	Logistics WBS 3104	Habitability WBS 3204	Subsystems WBS 3304
Food Management			
Oven		X	
Water Heater		X	
Utensils		X	
Stowage	X	X	
Food	X	X	
Crew Quarters			
Partitions		X	X
Desks/Consoles		X	X
Crew Gear			
Garments		X	
Bed Rolls		X	
Personal Items		X	
Space Suits		X	X
Restraints, IVA/EVA			
Cargo	X	X	X
Personnel	X	X	X
Lighting			
Interior	X	X	X
Exterior	X	X	X
Hygiene			
Fecal Tanks			X
Urine Tanks			X
Sink/Dryer			X
Hygiene/Medical Kits			X
Exerciser			X
Consumables			X
Support Structure		X	

Table 6-4 (Page 2 of 2)

TABULATION OF ITEMS IN CREW ACCOMMODATIONS SUBSYSTEM

Item	Distribution of Items: Logistics WBS 3104	Habitability WBS 3204	Subsystems WBS 3304
Water Management			
Wash Water Recovery		X	X
Water Dispenser		X	
Water Separator (Urine)			X
Water Supply		X	
Trash Management			
Compactor		X	
Canister/Storage		X	
Consumables		X	
Support Structure		X	
Flight Operations Environment			
Cameras and Film		X	
Sighting Equipment		X	
Recording Forms/Equipment		X	

Table 6-5

TABULATION OF ITEMS IN ELECTRICAL POWER SUBSYSTEM

Item	Distribution of Items: Logistics WBS 3105	Habitability WBS 3205	Subsystems WBS 3305
Solar Array			X
Batteries		X	X
Controls/Regulators		X	X
Wirings	X	X	X
Distribution Systems	X	X	X

Table 6-6

TABULATION OF ITEMS IN COMMUNICATIONS SUBSYSTEM

Item	Distribution of Items		
	Logistics WBS 3106	Habitability WBS 3206	Subsystems WBS 3306
Antenna - S band			X
- Ku band		X	
Processors - S band			X
- Ku band		X	
Internal Communications	X	X	X

Table 6-7 (Page 1 of 2)

TABULATION OF ITEMS IN DATA MANAGEMENT SUBSYSTEM

Item	Distribution of Items		
	Logistics WBS 3107	Habitability WBS 3207	Subsystems WBS 3307
Data Processing			
Speech Synthesizer	-	-	1
Computer	-	-	2
Data Adapter	-	-	2
C&W Logic Unit	-	-	1
PCM Unit	-	-	2
MUX/Demux	-	2	4
Loop Recorder	-	-	1
Maintenance Recorder	-	-	1
Timing Unit	-	-	1
Master Alarm Unit	-	-	1
Video Switching Unit	-	-	1

Table 6-7 (Page 2 of 2)

TABULATION OF ITEMS IN DATA MANAGEMENT SUBSYSTEM

Item	Distribution of Items		
	Logistics WBS 3107	Habitability WBS 3207	Subsystems WBS 3307
Instrumentation			
TV Camera	-	1	1
Signal Conditioning	-	3	6
Transducers	-	100	200
Display/Control			
Mission Timer	-	-	1
Event Timer	-	-	2
CRT/Keyboard	-	-	1
Display Processor	-	-	1
Remote Control Display	-	1	-
C&W Annunciator Assembly	-	1	-
Teletype	-	-	1
Video Monitor	-	-	1
Discrete Control/Display Panels	-	-	4
Computer Service Panel	-	-	1

Table 6-8

TABULATION OF ITEMS IN STABILIZATION AND CONTROL SUBSYSTEMS

Item	Distribution of Items		
	Logistics WBS 3108	Habitability WBS 3208	Subsystems WBS 3308
CMG's			X
Sensors, Controls			X

Table 6-9

TABULATION OF ITEMS IN PROPULSION SUBSYSTEM

Item	Distribution of Items: Logistics WBS 3109	Habitability WBS 3209	Subsystems WBS 3309
Thrusters	X	X	
Lines/Valves	X	X	X
Tanks	X		X

Table 6-10

TABULATION OF ITEMS IN ENVIRONMENTAL PROTECTION SUBSYSTEM

	Distribution of Items			
		Module		
Item	Logistics WBS 3110	Habitability WBS 3210	Subsystems WBS 3310	Payload Shell WBS 3410
Radiators		X	X	
Meteoroid Shield	X	X	X	X
External Insulation	X	X	X	X

Tables 6-11, 6-12, 6-13, and 6-14 present subsystem costs by module and by phase. The DDT&E costs shown for each module in Table 6-12 are determined by prorating the DDT&E costs for each subystem among the modules using that subystem; therefore, the DDT&E cost shown for any module is not representative of the cost that would be incurred if that module were developed separately. All four of the modules must be developed as a part of the same program for the estimates to be valid. Similarly the production costs are valid only if 4 logistic modules, 2 habitability modules, 2 subsystem modules, and 4 payload module shells are produced.

Table 6-11

SUBSYSTEMS COSTS BY PHASE

FY 1975 Dollars in Millions

Level 5 WBS No.	Description	Costs and Percents							
		DDT&E		Prod.		Oper.		Total	
		$	%	$	%	$	%	$	%
-01	Integrated Assembly and Checkout	34.14	11.6	30.02	15.2			64.16	10.6
-02	Structural/Mechanical	30.02	10.2	25.20	12.7	0.38	0.3	55.60	9.2
-03	ECLS	46.79	15.9	26.26	13.3	26.86	23.9	99.91	16.5
-04	Crew Accommodations	22.89	7.8	14.06	7.1	15.67	14.0	52.62	8.7
-05	Elect. Power	105.81	36.0	54.34	27.5	38.08	33.9	198.23	32.8
-06	Communications	19.12	6.5	17.55	8.9	11.41	10.2	48.08	8.0
-07	Data Management	16.67	5.7	11.25	5.7	6.94	6.2	34.86	5.8
-08	Stab. and Control	5.69	1.9	7.91	4.0	6.56	5.8	20.16	3.4
-09	Propulsion	1.40	0.5	7.59	3.8	6.30	5.6	15.29	2.5
-10	Env. Protection	11.36	3.9	3.62	1.8	0.15	0.1	15.13	2.5
Total		293.89	100.0	197.79	100.0	112.35	100.0	604.03	100.0
		(48.7%)		(32.7%)		(18.6%)		(100.0%)	

Table 6-12

SUBSYSTEM DDT&E COSTS BY MODULE*

FY 1975 Dollars in Millions

WBS No.	Subsystem	LM	HM	SM	PM Shell	Total	Percent
1	Integration	5.64	11.96	14.58	1.96	34.14	11.6
2	Struc/Mech.	7.92	6.99	11.48	3.63	30.02	10.
3	ECLS	7.85	12.52	26.42		46.79	15.9
4	Crew Accom.	1.57	11.60	9.72		22.89	7.8
5	Elec Pwr	14.42	27.48	63.91		105.81	36.0
6	Commun.	0.02	15.78	3.32		19.12	6.5
7	Data Mgnt		10.06	6.61		16.67	5.7
8	Stab/Control			5.69		5.69	1.9
9	Propulsion	0.74	0.33	0.33		1.60	0.5
10	Env. Protec.	3.00	3.03	2.65	2.68	11.36	3.9
Total		41.16	99.75	144.71	8.27	293.89	100.0
		(14.0%)	(34.0%)	(49.2%)	(2.8%)	(100.0%)	

*Costs are prorated between modules using each subsystem. The cost shown for an individual module's subsystem is not representative of the cost that would be incurred if that module's subsystem were developed separately.

Table 6-13

SUBSYSTEM PRODUCTION COSTS BY MODULE

FY 1975 Dollars in Millions

WBS No.	Subsystem	LM	HM	SM	PM Shell	Total	Percent
1	Integration	4.46	8.77	15.37	1.42	30.02	15.2
2	Struc/Mech	9.24	4.23	5.22	6.51	25.20	12.7
3	ECLS	0.77	10.69	14.80		26.26	13.3
4	Crew Accom.	0.67	4.96	8.43		14.06	7.1
5	Elec. Pwr	8.42	7.64	38.28		54.34	27.5
6	Commun.	0.05	13.04	4.46		17.55	8.9
7	Data Mgnt		5.49	5.76		11.25	5.7
8	Stab/Control			7.91		7.90	4.0
9	Propulsion	5.04	2.07	0.48	1.38	7.59	3.8
10	Env. Protec.	0.74	0.90	0.60		3.62	1.8
Total		29.39	57.79	101.31	9.30	197.79	100.0
		(14.9%)	(29.3%)	(51.2%)	(4.7%)	(100.0%)	

Table 6-14

SUBSYSTEM OPERATIONS COST BY MODULE

WBS No.	Subsystem	LM	HM	SM	PM Shell	Total	Percent
1	Integration						
2	Struc/Mech	0.14	0.06	0.08	0.10	0.38	0.3
3	ECLS	5.07	9.15	12.64		26.86	23.9
4	Crew Accom.	0.38	9.06	6.23		15.67	1.4
5	Elec Pwr	5.90	5.35	26.83		38.08	33.9
6	Commun.	0.03	8.48	2.90		11.41	10.2
7	Data Mgmt		3.39	3.55		6.94	6.2
8	Stab/Control			6.56		6.56	5.8
9	Propulsion	4.18	1.72	0.40		6.3	5.6
10	Env. Protec.	0.02	0.04	0.03	0.06	0.15	0.1
Total		15.72	37.25	59.22	0.16	112.35	100.0
		(14.0%)	(33.2%)	(52.7%)	(0.1%)	(100.0%)	

The subsystem development cost includes both engineering and ground test hardware costs. Table 6-15 defines the amount of hardware provided for development and qualification tests associated with each subsystem. Additional information on test hardware flow is presented in the discussion of test hardware in Paragraph 6.4. Most of the hardware planned for use in MOSC will already have been developed and qualified on other programs; therefore, the development costs in this MOSC estimate are believed to be realistic even though they are lower than the costs experienced on other programs which normally develop a larger amount of new hardware.

Table 6-15

SUBSYSTEM DEVELOPMENT AND QUALIFICATION TEST HARDWARE

Subsystem	Requirements as Number of Equivalent Units(1)
Structural/Mechanical	0.31
ECLS	0.52
Crew Accommodations	0.37
Electrical Power	0.86
Communications	0.38
Data Management	0.85
Stabilization and Control	0.76
Propulsion	0.18
Environmental Protection	0.19

Note: (1) Equivalent to first unit cost of one complete subsystem as required by one complete 4-module MOSC system.

6.3 GROUND SUPPORT EQUIPMENT

The system level GSE for the MOSC was divided into six subsystems. Table 6-16 tabulates the cost for each subsystem item by phase. The allocation of costs between the subsystems was derived using data from the very detailed analysis performed in the Phase B, Space Station Definition Study, Contract NAS8-25140.

Table 6-16

WBS 60 - GROUND SUPPORT EQUIPMENT

FY 1975 Dollars in Millions

		Phase Costs			Total Project	
WBS No.	Description	DDT&E	Prod.	Oper.	Cost	Percent
6001	Electrical	16.64	0.03	3.60	20.27	27.2
6002	Mechanical	5.04	0.01	0.02	5.07	6.8
6003	Hydraulic	14.37	0.00	3.66	18.03	24.2
6004	Software	12.39	0.11	2.37	14.87	19.9
6005	Launch Equip.	1.20	0.00	0.30	1.50	2.0
6006	Flight Support	12.39	0.11	2.37	14.87	19.9
60	TOTAL	62.03	0.27	12.32	74.61	100.0

6.4 SYSTEMS TEST AND EVALUATION

Systems Test and Evaluation, WBS 70, is divided into two subordinate details (Table 6-17). WBS 7001, Major Test Articles, contains the estimated cost of the hardware itself and WBS 70-02, System Test, is the estimated cost of the test labor. Figure 6-1 shows the flow of that hardware from the ground test to systems test and from systems test into the simulator. As shown in the figure, the total estimated cost of the hardware used in the systems test is $88.24 million. However $32.79 million or 37 percent of this hardware is obtained by a second usage of hardware surviving the development and qualification tests. To avoid double accounting, only the new hardware, $55.46 million, is charged to the systems test. Similarly, 33 percent of the hardware required for systems test is estimated to be used in the simulator/trainer.

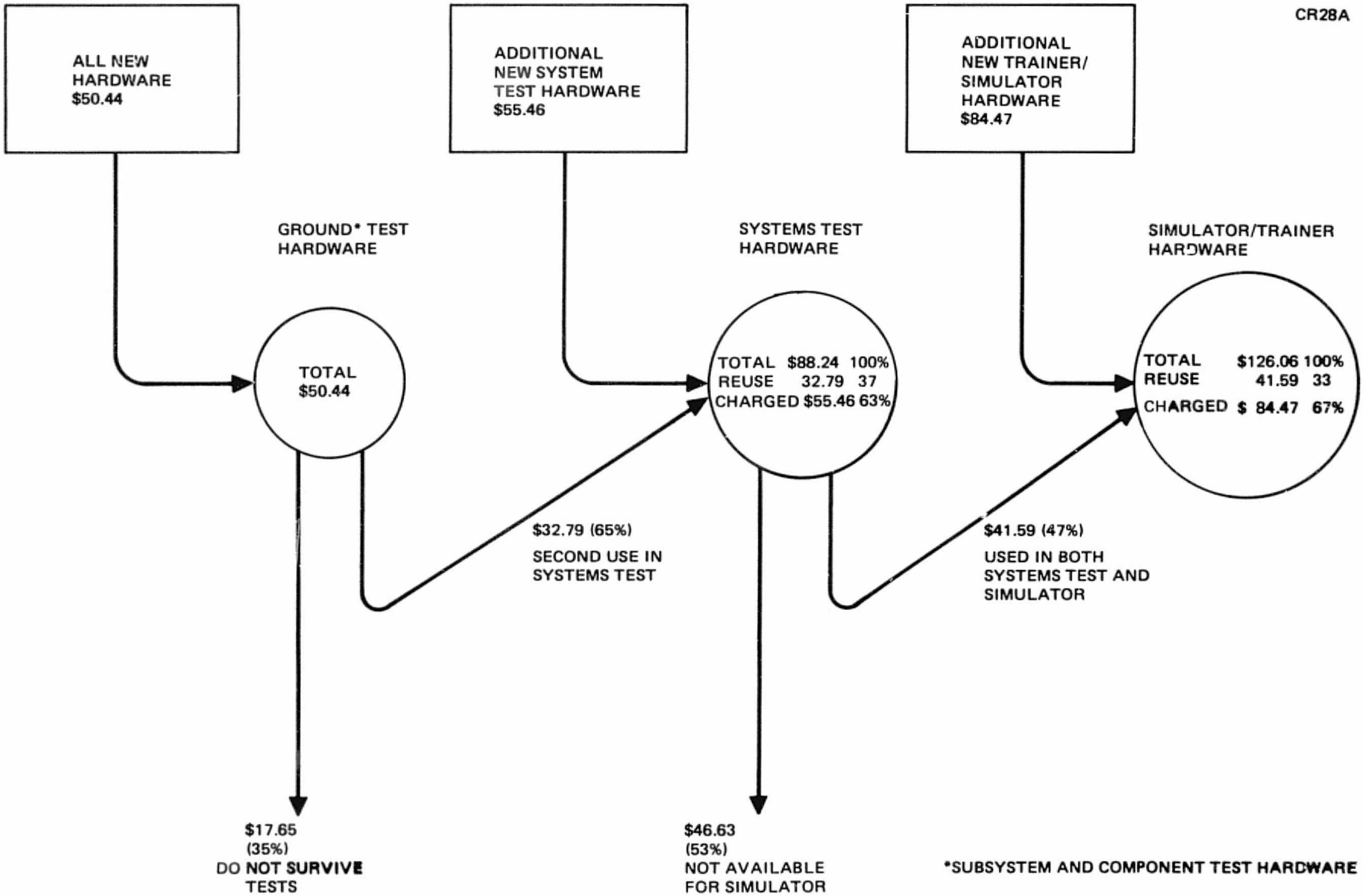

Figure 6-1. Results of Multiple Use of Test Hardware.
(See Figure 2-6 for Assumptions)
(Millions of FY 75 Dollars)

The distinction, especially near the later part of the development phase, between systems test hardware and simulator/trainer hardware will depend more on function than on identifying separate pieces of hardware. During the fourth year of the program, the same system or module may be used to check interfaces and functions that are used to orient flight crews and validate operating procedures. (See project schedule discussion in Section 3.2.)

Table 6-17

WBS 70 - SYSTEM TEST AND EVALUATION

FY 1975 Dollars in Millions

		Phase Costs			Total Project	
WBS No.	Description	DDT&E	Prod.	Oper.	Cost	Percent
7001	Major Test Articles	55.46			55.46	66.3
7002	System Test	28.24			28.24	33.7
70	TOTAL	83.70 (100%)			83.70 (100%)	100.0

6.5 LOGISTICS

Logistics, WBS 80, is divided into five subordinate cost items at the subsystem level (Table 6-18). The cost estimate for the simulator reflects the multiple use of hardware, as discussed in Section 6.5

6.6 GROUND OPERATIONS

Ground Operations, WBS 100, is divided into four subordinate items at the subsystem level (Table 6-19). The manpower required to perform the associated tasks was estimated in the following categories:

Level 5 Item	Sum of Manpower Estimates for -
10002 Maintenance and Refurb.	Refurbishment Planning
	Scheduled Maintenance/Refurbishment
	Unscheduled Maintenance/Refurbishment
	GSE Maintenance/Refurbishment
	Post-Maintenance Checkout
10003 Launch Operations	Mating and Checkout
	Prelaunch/Launch
	Post-Flight Safing
	Launch Site Servicing
10004 Non-Launch Site	Flight Control/Mission Support
	Astronaut/Flight Control
	Principal Investigation
	Communication Network Crew

The Non-Launch Site, WBS 10004, analysis placed contractor personnel only in the flight control/mission support crew, with approximately one contractor man for each eight NASA/Government men. The other crews (WBS 10002 and 10003) provided one contractor to approximately two NASA/Government men.

Table 6-18

WBS 80 - LOGISTICS

FY 1975 Dollars in Millions

		Phase Costs			Total Project	
WBS No.	Description	DDT&E	Prod.	Oper.	Cost	Percent
8001	Training - Consultation			0.37	0.37	0.3
8002	Transportation			0.73	0.73	0.7
8003	Inventory Control			0.29	0.29	0.3
8004	Training Aids			25.21	25.21	22.7
8005	Simulator			84.47	84.47	76.0
80	TOTAL			111.08 (100%)	111.08 (100%)	100.0

Table 6-19

WBS 100 - GROUND OPERATIONS

FY 1975 Dollars in Millions

		Phase Costs			Total Project	
WBS No.	Description	DDT&E	Prod.	Oper.	Cost	Percent
10001	Flight Test			0.00	0.00	–
10002	Maint/Refurb.			8.64	8.64	20.7
10003	Launch Ops.			24.77	24.77	59.2
10004	Non-Launch Site			8.40	8.40	20.1
100	TOTAL			41.81 (100%)	41.81 (100%)	100.0

Section 7
PROJECT FUNDING DISTRIBUTION

The project level funding distribution, displayed in Figure 7-1, is the result of relating costs and schedules beginning at the subsystem Level 5 and continuing cumulatively upward through the project level. The figure presents both annual and cumulative funding distributions. Peak year funding occurs in FY 1983 - about one year prior to IOC - and amounts to $236 million. For the total project, the funding distribution approximates a 74 percent beta distribution - $881 million, or 74 percent of the $1,185 million total life-cycle cost, is estimated to be expended by the end of FY 1985, or 50 percent of the total schedule time.

Additional tabular and graphic detail on the funding distributions is presented in Appendix F.

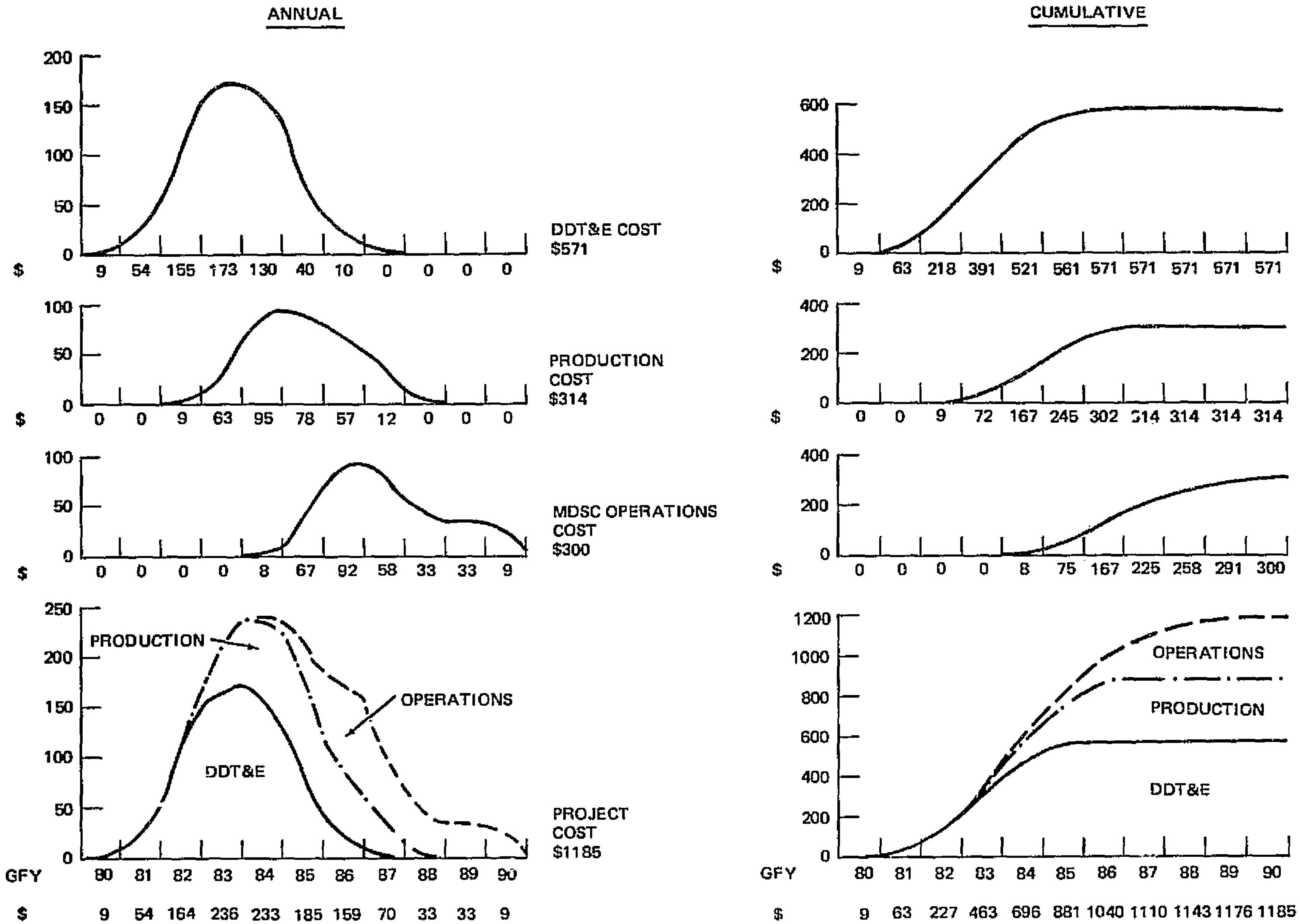

Figure 7-1. MOSC 4-Man Baseline Fa‹ility Funding Distribution by Year (Millions of FY 75 Dollars)

Appendix A

WORK BREAKDOWN STRUCTURE AND DICTIONARY FOR A MANNED ORBITAL SYSTEMS CONCEPT

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CONTENTS

INTRODUCTION

The proposed MDAC Manned Orbital Systems Concept (MOSC) project WBS Dictionary defines the scope of each WBS item. In doing so, it provides a means for locating the proper "home" for functions/tasks, as they are identified.

WORK BREAKDOWN STRUCTURE

The Manned Orbital Systems Concept WBS is a task-oriented display of both hardware and key functions that define the end product to be developed and produced. The WBS serves as a common framework for Program Definition in structuring the technical plan, development schedule, and cost definition.

The Manned Orbital Systems Concept Program will be accomplished in three phases. These phases are described as follows:

A. Design, Development, Test and Evaluation (DDT&E) - This phase consists of the cost of designing, developing, testing and evaluating an item. Specifically it includes such categories as the following: development engineering and development support, major test hardware, captive and ground tests, ground support equipment, tooling and special test equipment, site activation.

B. Production - It is defined as the costs associated with producing flight hardware through acceptance of the hardware by the Government including all costs associated with: (1) fabrication, assembly, and checkout of flight hardware, (2) ground test and factory checkout of flight hardware, (3) initial spares, and (4) maintenance of tooling and special test equipment.

C. Operation - Is defined as the cost associated with the following activities:

(1) Support Operations: (1) replacement of spares to support both operational airborne and ground hardware (not GSE), (2) sustaining engineering to support the production of spares and hardware modifications, and (3) maintenance of GSE and spares for GSE.

(2) Launch Operations: The costs for receiving the flight hardware, prelaunch assembly into the Orbiter vehicle, test and checkout, servicing, launching, and post-launch support directly related to the Manned Orbital Systems Concept Project. Maintenance and refurbishment are specifically excluded from the launch operations category.

(3) Mission Operations: The cost of mission control, mission planning, flight crew training, simulation aids required for crew training, and in-flight mission costs, directly related to the Manned Orbital Systems Concept Project.

(4) Maintenance and Refurbishment Operations: The cost of activities required to maintain and restore a previously flown reusable system to a flight readiness condition.

Table A-1

EFFECTIVITY OF WBS ELEMENTS

WBS Element	Contract Phase		
	DDT&E	Production	Operations
100-10 Project Management	X	X	X
20 System Engineering and Integration		Summary Level	
20-01 MOSC Systems Engineering	X	X	
20-02 Module to Orbiter Integration	X	X	
20-03 Module Systems Integration	X	X	
20-04 Sustaining Engineering		X	X
30 Manned Orbital Systems Concept Module		Summary Level	
31 Logistic Module	X	X	X
32 Habitability Module	X	X	X
33 Subsystem Module	X	X	X
34 Payload Module Shell	X	X	X
3X-01 Integration, Assembly & Checkout	X	X	
3X-02 Structural/Mechanical	X	X	X
3X-03 Environmental Control/Life Support	X	X	X
3X-04 Crew Accommodation	X	X	X
3X-05 Electrical Power	X	X	X
3X-06 Communications	X	X	X
3X-07 Data Management	X	X	X
3X-08 Stabilization and Control	X	X	X
3X-09 Propulsion	X	X	X
3X-10 Environmental Protection	X	X	X
40 Integral Experiments	- - -	- - - - - -	- - -
50 Experiment Integration	- - -	- - - - - -	- - -
60 Ground Support Equipment		Summary Level	
60-01 Electrical	X	X	X
60-02 Mechanical	X	X	X
60-03 Hydraulic	X	X	X
60-04 Software	X	X	X
60-05 Launch Equipment	X	X	X
60-06 Flight Support Equipment	X	X	X
70 System Test and Evaluation		Summary Level	
70-01 Major Test Articles	X		
70-02 System Test	X		
80 Logistics		Summary Level	
80-01 Training - Consultation			X
80-02 Transportation			X
80-03 Inventory Control			X
80-04 Training Aids			X
80-05 Simulator			X
90 Facilities	X		
100 Ground Operations		Summary Level	
100-01 Flight Test Operations			X
100-02 Maintenance/Refurbishment			X
100-03 Launch Operations			X
100-04 Non-Launch Site			
110 Flight Operations		(Excluded by NASA Direction)	

MANNED ORBITAL SYSTEMS
CONCEPT PROJECT

WBS DICTIONARY

WBS 100 MOSC PROJECT

This summary element contains all labor and materials required to design, develop, manufacture, procure, assemble, test, checkout and deliver the MOSC Modules to the Marshall Space Flight Center. Also provided are test articles, mock-ups, support equipment, training and flight support activities.

This element is subdivided into:

WBS	TITLE
-10	Project Management
-20	System Engineering and Integration
-30	Manned Orbital Systems Concept Module(s)
-40	Integral Experiments
-50	Experiment Integration
-60	Ground Support Equipment
-70	System Test and Evaluation
-80	Logistics
-90	Facilities
-100	Ground Operations
-110	Flight Operations

WBS 100-10 or WBS -10 PROJECT MANAGEMENT

This element contains the effort associated with planning, scheduling, budgeting, controlling and directing project activities. Also included is the accomplishment of such disciplines as Configuration Management, Performance Management, GFE Management, and Data Management. Customer liaison and contract administration are also performed in this element.

WBS -20 SYSTEM ENGINEERING AND INTEGRATION

This element summarizes the MOSC systems engineering task of directing and controlling a totally integrated engineering effort, including requirements analysis and integration, system definition, system test definition, interfaces, safety, reliability, maintainability, configuration management, quality engineering, and technology utilization.

This element is subdivided into:

WBS	TITLE
-20-01	MOSC Systems Engineering
-20-02	Module to Orbiter Integration
-20-03	Module Systems Integration
-20-04	Sustaining Engineering

WBS -20-01 MOSC SYSTEMS ENGINEERING

This element pertains to the systems engineering effort associated with the design, development, production and test of the MOSC. Included are analyses required to verify compatibility of designs with requirements; to control and direct the engineering activities; and to make cost/performance tradeoffs. Also included are engineering planning, studies, technology utilization, technical risk assessment, reliability engineering, safety engineering, quality engineering, configuration requirements analysis, and associated support required to perform the MOSC systems engineering task.

WBS -20-02 MODULE-TO-ORBITER INTEGRATION

This element provides for that engineering effort required to define and maintain the MOSC interface with the Orbiter, including analysis and identification of MOSC test and checkout operations affecting that interface, analysis and identification of MOSC configuration changes affecting the interface, and evaluation/coordination of recommended changes to the interface.

WBS -20-03 MODULE SYSTEMS INTEGRATION

This element includes all systems engineering and integration effort associated with combining the MOSC systems into a total functioning MOSC. Included are system analysis, design, test, and evaluation required to ensure the efficient accomplishment of this task, preparation, submittal and maintenance of Interface Control Documents; studies and analyses for system optimization, cost effectiveness and compatibility; technical risk assessment to identify potential major problems; and failure mode and effect analysis.

WBS -20-04 SUSTAINING ENGINEERING

This element provides all sustaining engineering effort, following DDT&E, required for the MOSC project after the completed, assembled concept has been checked out for full flight certification and delivered. Also included are in-plant engineering liaison support of operational activities and the sustaining engineering support required at the launch sites during the operations phase. Activities would include further allocation of performance requirements for the vehicle into subsystem requirements, evaluation of vehicle and GSE performance, maintainability analysis, etc. Excluded are those activities that pertain to major hardware modification required to meet new performance specifications.

WBS -30 MANNED ORBITAL SYSTEMS CONCEPT MODULES

This summary element contains all the labor and materials required to design, develop, manufacture, procure, assemble, test, checkout and deliver flight units and operational spare

parts for all the individual modules. Subsystem and component development and qualification tests are also conducted. The effort associated with integration, assembly test and checkout of the combined modules included in WBS 20-03 is specifically excluded from this item.

This element is subdivided into:

WBS	Title
-31	Logistics Module
-32	Habitability Module
-33	Subsystem Module
-34	Payload Module

The following Systems Level 4.5 elements (WBS 31 through 34) are summary elements underneath WBS 30. Each of these subelements contains all the labor and materials required to design, develop, manufacture, procure, assemble, test, check out, and deliver flight units and initial and operational spare parts for that particular module. Subsystem and component development and qualification hardware and test labor are included but systems level hardware and tests assigned to WBS 70 are excluded. The modules are defined as follows:

WBS -31 LOGISTICS MODULE

The Logistics Module is a system carried into orbit by the Shuttle for transport of cargo to the MOSC orbital facility and for in-orbit consumables storage in support of the MOSC facility.

WBS -32 HABITABILITY MODULE

The Habitability Module is a system carried into orbit by the Shuttle and remaining in space when the Shuttle returns. It contains the crew living and sleeping quarters, food preparation facilities and some work stations.

WBS -33 SUBSYSTEM MODULE

The Subsystem Module is a system carried into orbit by the Shuttle and remaining in space when the Shuttle returns. It is connected to the Habitability Module and contains crew hygiene facilities, solar arrays, and the main facility control center.

WBS -34 PAYLOAD MODULE SHELL

The Payload Shell is a system carried into orbit by the Shuttle for transporting the experiment hardware into orbit. It connects to the Habitability and Subsystem Modules facility, and houses the experiment equipment as long as the experiment is deployed in space. At present, this module includes only the structural shell and environmental protection subsystems.

WBS -31 thru WBS -34 Each of these System elements (WBS 31 through 34) is subdivided into the following elements. The check marks indicate if the subsystem exists in each module as it is defined in the baseline 4-man MOSC configuration.

WBS	TITLE	MODULE			
		-31	-32	-33	-34
-3X-01	Integration, Assembly & Checkout	x	x	x	x
-3X-02	Structural/Mechanical	x	x	x	x
-3X-03	Environmental Control/Life Support	x	x	x	
-3X-04	Crew Accommodation	x	x	x	
-3X-05	Electrical Power	x	x	x	
-3X-06	Communications	x	x	x	
-3X-07	Data Management		x	x	
-3X-08	Stabilization and Control			x	
-3X-09	Propulsion	x	x	x	
-3X-10	Environmental Protection	x	x	x	x

Each of the subsystem elements (WBS 3X02 through WBS 3X10) contains all labor and material necessary to design, manufacture, procure, assembly, test (development and/or verification).

inspect and checkout that particular subsystem. Also included are: design and fabrication/purchase of test specimens and operational spares, the preparation of engineering drawings, procedures, specifications; supplier qualification and coordination, design and fabrication of tooling; production planning. The specific type effort or equipment included in each element is listed under its own heading.

WBS -3X-01 INTEGRATION, ASSEMBLY AND CHECKOUT

This element contains all labor and material required to integrate the various subsystems into an individual module and the individual modules into a viable module system. Final assembly, including attachment and installation hardware, final factory acceptance operations, packaging/crating and shipment are included. Also included are the preparation of final factory acceptance checkout procedures, manufacturing liaison and the coordination and accomplishment of customer acceptance of the completed articles.

WBS -3X-02 STRUCTURAL/MECHANICAL

This element includes the primary structural/pressure shell, hatches, docking adapter and internal floor and equipment racks. The mechanism required to rotate the solar arrays is included. The partitions, doors, and other secondary structural elements associated with the crew quarters (WBS 3X04) are specifically excluded.

WBS -3X-03 ENVIRONMENTAL CONTROL/LIFE SUPPORT

This element includes atmospheric control, supply, circulating and purifying equipment; the thermal control equipment for both crew and equipment including cold plates and coolant circulating equipment; and emergency life support equipment such as fire and smoke detection, emergency life support pallets and portable life support equipment. It excludes hygiene, waste management, water recovery equipment as well as the external radiators.

WBS -3X-04 <u>CREW ACCOMMODATIONS</u>

This element includes the food management, storage, and processing equipment as well as the food itself; the crew quarters including partitions, doors, desks, bunks, and work consoles; equipment and personnel restraints and cargo handling equipment for both IVA and EVA, handrails and storage bags; personal gear, off duty items, garments, towels, bed rolls, and sparesuits; lighting including interior/exterior, portable/fixed, spot/general illumination; hygiene, waste management, water management including storing, processing and recovery; personnel exerciser; and flight operations equipment including cameras, film, mirrors, binoculars, etc.

Specifically excluded is the water heating dispensing equipment associated with food preparation.

WBS -3X-05 <u>ELECTRICAL POWER</u>

This element includes the solar array, batteries, electrical distribution equipment, all wiring such as associated with sensor instrumentation and lighting, power regulation and control equipment. Specifically excluded is the solar array rotating equipment included in WBS 3X02 and the electrical equipment included in the docking adapter.

WBS -3X-06 <u>COMMUNICATIONS</u>

This element includes the antennae, transmitters, receivers, final signal processors, amplifiers and internal audio control center.

WBS -3X-07 DATA MANAGEMENT SUBSYSTEM

The data management subsystem consists of all the necessary equipment to transfer, store, and process data to and from users and subsystems. It is a modularized multiprocessor specifically consisting of processors, memory storage units, switching units, peripheral devices, data adapters, coders, decoders, time synchronous generator, film scanners and reducers, analog tape storage, search and control equipment, signal conditioning and demodulation equipment, and entertainment units.

WBS -3X-08 STABILIZATION AND CONTROL

This element includes gyros, horizon sensors, trackers, and the guidance commands required to determine and control the MOSC position and orientation.

WBS -3X-09 PROPULSION

This element includes propulsion nozzles for attitude control, orbit keeping, orbit changing and associated propellant tankage, lines valves and controls.

WBS -3X-10 ENVIRONMENTAL PROTECTION

The element includes the structure and fluid equipment located outside the pressure shell associated with the external radiator and meteoroid shield. It also includes the external thermal insulation. It specifically excludes the fluid equipment associated with the docking adapter.

WBS -40 INTEGRAL EXPERIMENTS

This WBS element is used for reference purposes only; all data including cost will be provided by NASA.

C-2

WBS -50 EXPERIMENT INTEGRATION

This element includes all labor and material required to integrate the various experiments only into the Payload Module Shell. It includes all effort associated with handling, installation, assembly and checkout of the experiment(s) from the time they are received for installation into the module until it is launched. It includes preparation of interface drawings, acceptance checkout procedure, manufacturing liaison and coordination and accomplishment of customer acceptance of the completed integration of the experiment in the systems concept module.

WBS -60 GROUND SUPPORT EQUIPMENT

This element summarizes the labor and materials required to design, manufacture, procure, assemble, test, checkout, and deliver all the sets of the GSE hardware and software required by the MOSC and to provide initial and operational GSE spares.

This element is subdivided into:

WBS	TITLE
-60-01	Electrical Equipment
-60-02	Mechanical Equipment
-60-03	Hydraulic Equipment
-60-04	Software
-60-05	Launch Equipment
-60-06	Flight Support Equipment

WBS -60-01 ELECTRICAL EQUIPMENT

This element contains all the power interconnecting cables, consoles and test sets required to test, check out, isolate malfunctions and assist in servicing and repairing all electrical and avionics equipment used in the MOSC excluding experiment hardware.

WBS -60-02 MECHANICAL EQUIPMENT

This element contains the GSE required to handle, transport, position, protect, access and ship the MOSC flight hardware.

WBS -60-03 HYDRAULIC EQUIPMENT

This element contains servicing equipment to provide the fluids or expendables to the MOSC during checkout of the thermal conditioning equipment, water management, cooling system, atmospheric supply and propellant equipment.

WBS -60-04 SOFTWARE

This element includes all programs, control tapes and other non-hardware items including procedures and instruction manuals required to service the MOSC.

WBS -60-05 LAUNCH EQUIPMENT

This element includes the special equipment required at the launch site to support, service, control and monitor the MOSC during preparation and launch provided such equipment is not already included in the GSE required for manufacture, handling and checkout.

WBS -60-06 FLIGHT SUPPORT EQUIPMENT

This element includes any specialized equipment required to support planning, flight operations, communications, command and control of the MOSC, and logistics provisioning. Requirements should be minimal since use of existing capability will be designed for wherever possible. Ground network, satellite and Shuttle communications, command and control functions are excluded.

WBS -70 SYSTEM TEST AND EVALUATION

This element summarizes the effort required to plan and perform the integrated subsystem, system and vehicle level tests on the vehicle and ground support hardware that are necessary to evaluate and verify the integrity and performance of the hardware.

This section is subdivided as follows:

WBS	TITLE
-70-01	Major Test Articles
-70-02	System Test

WBS -70-01 MAJOR TEST ARTICLES

This element includes the labor and material required for the design, tooling and fabrication of major test articles to provide design development information necessary to verify design concepts.

NOTE: This element specifically excludes test specimens which are produced under WBS Element -30.

WBS -70-02 SYSTEM TEST

In this element are performed the planning, coordination, design, set-up, conduct and evaluation of system-level development and verification tests.

NOTE: This element specifically excludes flight testing which is accomplished under WBS Element -110.

WBS -80 LOGISTICS

This element includes all labor and material for the training, handling and transportation activities required to support the design, development, operation and maintenance of the module.

Included are the training services, devices, accessories, aids, equipment, and parts used to facilitate instruction through which personnel will acquire sufficient concepts, skills, and aptitudes to operate and maintain the system with maximum efficiency. Also included are the handling and transportation requirements for the module during its transit mode from the point of manufacture to the launch site and the pre-launch and maintenance/refurbishment operations.

This element is subdivided into:

WBS	ITEM
-80-01	Training - Consultation
-80-02	Transportation
-80-03	Inventory Control
-80-04	Training Aids
-80-05	Simulator

WBS -80-01 TRAINING - CONSULTATION

This element includes the cost of the contractor personnel that provide technical consultation and support to the NASA personnel training the NASA MOSC flight and ground crews.

WBS -80-02 TRANSPORTATION

The item contains the cost of transporting the MOSC flight units, simulator/trainer, spares and GSE from the fabricating facility to the initial using location.

WBS -80-03 INVENTORY CONTROL

This element contains the cost associated with warehousing, ordering, and maintaining a supply of flight hardware and GSE spares.

WBS -80-04 TRAINING AIDS

This element contains the models, visual aids, illustrations, and manuals used to train the flight and ground crews required by the MOSC excluding the simulator.

WBS -80-05 SIMULATOR

This element contains the hardware and software associated with the flight quality, high fidelity simulator used for training and mission analysis tasks.

WBS -90 FACILITIES

If new facilities or modifications to existing facilities are required, they are provided in this WBS element. Included are the planning, coordination, design, fabrication, procurement, inspection, installation, set-up, checkout, acceptance, and activation of these facilities. Facility operation and maintenance are provided in this element: that related to Manufacturing Facilities is a manufacturing cost, and that associated with Launch and Flight Operations is an Operations cost.

WBS -100 GROUND OPERATIONS

This WBS element summarizes all effort associated with the planning, coordination and implementation of launch activities and maintenance/refurbishment for the MOSC. The overall launch site handling and checkout operations will not be performed by the Manned Orbital Systems Concept Project.

This element is subdivided as follows:

WBS	TITLE
-100-01	Flight Test Operations
-100-02	Maintenance/Refurbishment
-100-03	Launch Operations
-100-04	Non-Launch Site Operations

WBS -100-01 FLIGHT TEST OPERATIONS

This element contains those activities associated with the early flights that are peculiar to monitoring these flights to verify that the in-orbit performance of the overall vehicle and its equipment conforms to the project requirements. It includes any additional planning, additional inspection and other additional effort associated specifically with the test aspects of the flight. It excludes effort associated with the normal test accomplished by the experiments themselves and any other effort normally required by all operational flights.

WBS -100-02 MAINTENANCE/REFURBISHMENT

The maintenance and/or refurbishment of flight hardware takes place in this element. Included are the coordination activities leading to the establishment of requirements, procedure preparation and validation, participation in working groups, liaison between the maintenance/refurbishment site and the home plant, post-flight inspection of flight hardware, conduct of maintenance/refurbishment tasks, revalidation and functional checkout.

WBS -100-03 LAUNCH OPERATIONS

This element contains all contractor effort at the launch site required to conduct module launch operations. Included are such tasks as coordination of schedules, preparation of countdown procedures, participation in working groups, liaison between the launch site and home plant, representation during the conduct of the launch countdown.

WBS -100-04 NON-LAUNCH SITE OPERATIONS

This element contains all contractor effort in support of the launch and flight operations which is accomplished at locations other than the launch site. It includes home plant planning and support, mission control and surveillance, data reduction, astronaut coordination activities,

and communication network support activities for the MOSC. It excludes this type of item for Shuttle and the effort contributed by NASA personnel.

A. MISSION PLANNING - the contractor activities associated with the establishment of mission requirements, the preparation of in-orbit procedures, the preparation of crew timelines, the coordination of earth-to-orbit communications and data requirements, and participation in mission planning working groups.

B. FLIGHT CONTROL AND EVALUATION - includes those contractor activities peculiar to in-flight operation of the MOSC. Post-flight quick-look evaluation of data and the preparation (i.e., formatting) of post-flight reports occur in this element.

   Subsystems' in-flight performance data for the laboratory will be reduced and evaluated to determine maintenance and refurbishment requirements.

WBS -110 FLIGHT OPERATIONS

This element includes all in-orbit activities performed by MOSC or Orbiter NASA Flight Crews.

Appendix B
DETAIL COST ESTIMATES

The tabulation which follows includes the detail cost estimates for each WBS element and for each phase for WBS Levels 3 - Project, 4 - System, 4.5 - System, and 5 - Subsystem.

WBS	COST ELEMENT	DDT+E: ENGINEERING DESIGN AND DEVELOPMENT	DDT+E: GROUND TEST HARDWARE	DDT+E: TOTAL	PRODUCTION: VEHICLE PRODUCTION	PRODUCTION: INITIAL SPARES	PRODUCTION: TOTAL	OPERATIONS: OPERATIONAL ACTIVITY	OPERATIONS: OPERATIONAL SPARES	OPERATIONS: TOTAL	TOTAL
10	TOTAL PROJECT MGT.	26.58	6.71	33.2	14.87	.06	14.93	8.35	5.68	14.03	62.26
20	TOTAL SYST. ENGR.	94.24	.00	94.24	100.63	.00	100.63	7.96	.00	7.96	202.84
30	TOTAL MOSC-ALL MOD	243.45	50.44	293.89	196.82	.97	197.79	6.18	106.17	112.35	604.03
40	TOTAL EXPERIMENTS	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
50	TOTAL EXPER. INTGR.	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
60	TOTAL GSE	62.03	.00	62.03	.00	.27	.27	.00	12.32	12.32	74.61
70	TOTAL SYST. TEST +	.00	83.69	83.69	.00	.00	.00	.00	.00	.00	83.69
80	TOTAL LOGISTICS	.00	.00	.00	.00	.00	.00	111.07	.00	111.07	111.07
90	TOTAL FACILITIES	4.25	.00	4.25	.00	.00	.00	.00	.00	.00	4.25
100	TOTAL GROUND OPS.	.00	.00	.00	.00	.00	.00	41.81	.00	41.81	41.81
110	TOTAL FLIGHT OPS.	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
	TOTAL PROJECT	430.86	140.83	571.40	312.33	1.30	313.62	175.37	124.17	299.54	1184.56

		DDT+E			PRODUCTION			OPERATIONS			
WBS	COST ELEMENT	ENGINEERING DESIGN AND DEVELOPMENT	GROUND TEST HARDWARE	TOTAL	VEHICLE PRODUCTION	INITIAL SPARES	TOTAL	OPERATIONAL ACTIVITY	OPERATIONAL SPARES	TOTAL	TOTAL
2001	MOSC SYST. ENGR	53.36	.00	53.36	14.42	.00	14.42	.00	.00	.00	67.77
2002	MODULE TO ORB. INT	3.35	.00	3.35	3.62	.00	3.62	.00	.00	.00	6.96
2003	INTGR. MOD. TO MOD	37.54	.00	37.54	49.21	.00	49.21	.00	.00	.00	86.75
2004	SUST. ENGR.	.00	.00	.00	33.39	.00	33.39	7.96	.00	7.96	41.36
20	TOTAL SYST. ENGR.	94.24	.00	94.24	100.63	.00	100.63	7.96	.00	7.96	202.84
3101	INTGR. ASSY. + C/O	5.64	.00	5.64	4.46	.00	4.46	.00	.00	.00	10.10
3102	STRUCT./MECH.	7.28	.65	7.93	9.23	.01	9.24	.00	.14	.14	17.31
3103	ECLS	7.68	.17	7.85	.73	.04	.77	.00	5.07	5.07	13.69
3104	CREW ACCOM.	1.56	.01	1.57	.66	.00	.67	.00	.38	.38	2.62
3105	ELECTRICAL POWER	12.66	1.77	14.43	8.35	.06	8.42	.00	5.90	5.90	28.74
3106	COMMUNICATIONS	.01	.01	.02	.05	.00	.05	.00	.03	.03	.09
3109	PROPULSION	.56	.18	.74	5.03	.00	5.04	.00	4.18	4.18	9.96
3110	ENVIRON. PROT.	2.95	.05	3.00	.74	.00	.74	.00	.02	.02	3.77
31	LOGISTIC MOD.	38.33	2.83	41.16	29.26	.13	29.39	.00	15.72	15.72	86.27
3201	INTGR. ASSY. + C/O	11.96	.00	11.96	8.77	.00	8.77	.00	.00	.00	20.73
3202	STRUCT./MECH.	6.25	.74	6.99	4.22	.00	4.23	.00	.06	.06	11.29
3203	ECLS	9.14	3.38	12.52	10.61	.08	10.69	.00	9.13	9.13	32.34
3204	CREW ACCOM.	10.16	1.43	11.60	4.92	.04	4.96	6.18	2.89	9.06	25.62
3205	ELECTRICAL POWER	23.67	3.81	27.48	7.58	.06	7.64	.00	5.35	5.39	40.48
3206	COMMUNICATIONS	13.02	2.76	15.78	13.00	.05	13.05	.00	8.48	8.48	37.31
3207	DATA MANAGEMENT	7.48	2.58	10.06	5.45	.04	5.49	.00	3.39	3.39	18.94
3209	PROPULSION	.26	.08	.33	2.07	.00	2.07	.00	1.72	1.72	4.12
3210	ENVIRON. PROT.	2.94	.08	3.03	.89	.00	.89	.00	.04	.04	3.96
32	HABITABILITY MOD.	84.88	14.87	99.75	57.51	.28	57.79	6.18	31.07	37.25	194.78
3301	INTGR. ASSY. + C/O	14.58	.00	14.58	15.37	.00	15.37	.00	.00	.00	29.95
3302	STRUCT./MECH.	9.54	1.95	11.48	5.21	.00	5.22	.00	.08	.08	16.78
3303	ECLS	22.46	3.95	26.42	14.69	.11	14.80	.00	12.64	12.64	53.86
3304	CREW ACCOM.	8.35	1.37	9.72	8.37	.06	8.43	.00	6.23	6.23	24.38
3305	ELECTRICAL POWER	45.85	18.06	63.91	38.00	.29	38.28	.00	26.83	26.83	129.02
3306	COMMUNICATIONS	2.30	1.02	3.32	4.44	.02	4.46	.00	2.90	2.90	10.68
3307	DATA MANAGEMENT	3.95	2.66	6.61	5.70	.06	5.76	.00	3.55	3.55	15.92
3308	STABIL. + CONTROL	2.59	3.10	5.69	7.90	.01	7.91	.00	6.56	6.56	20.16
3309	PROPULSION	.20	.13	.33	.48	.00	.48	.00	.40	.40	1.21
3310	ENVIRON. PROT.	2.58	.07	2.65	.60	.00	60	.00	.03	.03	3.96
33	SUBSYST.MOD.	112.40	32.31	144.71	100.76	.55	101.31	.00	59.22	59.22	305.24
3401	INTGR. ASSY. + C/O	1.96	.00	1.96	1.42	.00	1.42	.00	.00	.00	3.38
3402	STRUCT./MECH.	3.28	.35	3.63	6.50	.01	6.51	.00	.10	.10	10.24
3410	ENVIRON. PROT.	2.60	.07	2.68	1.37	.01	1.38	.00	.06	.06	4.11
34	PAYLD. MOD. SHELL	7.84	.43	8.27	9.29	.01	9.30	.00	.16	.16	17.73
30	TOTAL MOSC-ALL MOD	243.45	50.44	293.89	196.82	.97	197.79	6.18	106.17	112.35	604.03

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WBS	COST ELEMENT	DDT&E: ENGINEERING DESIGN AND DEVELOPMENT	DDT&E: GROUND TEST HARDWARE	DDT&E: TOTAL	PRODUCTION: VEHICLE PRODUCTION	PRODUCTION: INITIAL SPARES	PRODUCTION: TOTAL	OPERATIONS: OPERATIONAL ACTIVITY	OPERATIONS: OPERATIONAL SPARES	OPERATIONS: TOTAL	TOTAL
6001	ELECTRICAL	16.64	.00	16.64	.00	.03	.03	.00	3.60	3.60	20.27
6002	MECHANICAL	5.04	.00	5.04	.00	.01	.01	.00	.02	.02	5.07
6003	HYDRAULIC	14.37	.00	14.37	.00	.00	.00	.00	3.66	3.66	18.03
6004	SOFTWARE	12.39	.00	12.39	.00	.11	.11	.00	2.37	2.37	14.87
6005	LAUNCH EQUIP.	1.20	.00	1.20	.00	.00	.00	.00	.30	.30	1.50
6006	FLIGHT SUPPORT	12.39	.00	12.39	.00	.11	.11	.00	2.37	2.37	14.87
60	TOTAL GSE	62.03	.00	62.03	.00	.27	.27	.00	12.32	12.32	74.61
7001	MAJOR TEST ART.	.00	55.45	55.45	.00	.00	.00	.00	.00	.00	55.45
7002	SYSTEM TEST	.00	28.24	28.24	.00	.00	.00	.00	.00	.00	28.24
70	TOTAL SYST. TEST +	.00	83.69	83.69	.00	.00	.00	.00	.00	.00	83.69
8001	TRAINING-CONSULT.	.00	.00	.00	.00	.00	.00	.37	.00	.37	.37
8002	TRANSPORTATION	.00	.00	.00	.00	.00	.00	.73	.00	.73	.73
8003	INVENT. CONTROL	.00	.00	.00	.00	.00	.00	.29	.00	.29	.29
8004	TRAINING AIDS	.00	.00	.00	.00	.00	.00	25.21	.00	25.21	25.21
8005	SIMULATOR	.00	.00	.00	.00	.00	.00	84.46	.00	84.44	84.46
80	TOTAL LOGISTICS	.00	.00	.00	.00	.00	.00	111.07	.00	111.07	111.07
10001	FLIGHT TEST	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
10002	MAINT./REFURB.	.00	.00	.00	.00	.00	.00	8.64	.00	8.64	8.64
10003	LAUNCH OPS.	.00	.00	.00	.00	.00	.00	24.77	.00	24.77	24.77
10004	NON LAUNCH SITE	.00	.00	.00	.00	.00	.00	8.40	.00	8.40	8.40
100	TOTAL GROUND OPS.	.00	.00	.00	.00	.00	.00	41.81	.00	41.81	41.81

Appendix C
NASA COST DATA FORM A(1) - NONRECURRING (DDT&E)

The MOSC Cost Data Forms A(1) - Non-Recurring (DDT&E), for WBS elements through Subsystem Level-5, are presented in this appendix. The definitions of each column on the form are as follows:

Identification Number: The appropriate WBS code corresponding to the item of cost.

WBS Identification: The alphanumeric nomenclature of the item from the WBS.

WBS Level: The level at which the cost is accumulated.

Level 3 - Program
Level 4 - System (Integrated Modules)
Level 4.5 - System (Individual Module)
Level 5 - Subsystem

Expected Costs: The cost estimate for the WBS item.

Confidence Rating: Reference Table C-1.

Td: The time in months required to design, develop, test, and evaluate the designated WBS line item.

Ts: The lead time in months measured from the start of Td to the initial operational capability (IOC), the launch milestone date.

Spread Function: The spread function column is similar for all three data forms. The spread function is an index number representing a cost

distribution curve which the estimator recommends for the time phasing of costs over the Td time span. The index number represents the percentage of total cost (of the WBS item for the program phase) expected to be expended in 50 percent of the Td/time span. At summary levels the spread functions are weighted averages of the spread functions of constituent WBS elements at subordinate levels.

Table C-1
CONFIDENCE LEVEL GROUPS FOR COST ESTIMATES

	CONFIDENCE LEVEL 1 LOW	CONFIDENCE LEVEL 2 MEDIUM LOW	CONFIDENCE LEVEL 3 MEDIUM HIGH	CONFIDENCE LEVEL 4 HIGH
ESTIMATING CONDITIONS	Estimating Time and Information Access Completely inadequate amount of time provided to make the estimate or there is a complete lack of access to useful data sources. Ground Rules and Assumptions No guidance was provided on ground rules and all assumptions made by the estimator were arbitrary.	Estimating Time and Information Access A very short due date or major problems of access to available data tend to make this estimate highly uncertain. Ground Rules and Assumptions Very little guidance was provided relative to ground rules. Most of the assumptions made by the estimator were considered quite arbitrary.	Estimating Time and Information Access A more accurate estimate could have been made if freer access or more time had been available to research known data sources. Ground Rules and Assumptions Ground rules were generally adequate. Many of the assumptions were authenticated but a substantial number are considered questionable.	Estimating Time and Information Access There were minor problems of access to available data and there was generally sufficient time to define and cost the item. Ground Rules and Assumptions Major ground rules were provided and most of the assumptions were authenticated.
NATURE OF THE ITEM	State-of-the-Art The item is substantially beyond the current state-of-the-art. Major development work is required. Production Experience No production of any kind has been started.	State-of-the-Art The item is slightly beyond the state-of-the-art and some development work will be required. Production Experience Experimental laboratory fabrication of a similar item is in process.	State-of-the-Art The item is within the state-of-the-art but no commercial counterpart exists. Production Experience A prototype of the item has been produced.	State-of-the-Art The item will involve a minor modification of commercial or standard aerospace issue items. Production Experience the item has been produced in limited quantity.
ITEM DESCRIPTION	Specification Status No work on a specification has started. Operating Program Characteristics None of the OPC for using the item have been formulated.	Specification Status Work on a specification is in an early stage and only general requirements are identified. Operating Program Characteristics The general outline of the OPC under which the item will be used has been only tentatively defined and many specific details are lacking.	Specification Status A specification for the item has not been completed but a specification on a similar item is available. Operating Program Characteristics The general outline of the OPC has been formulated but many specific details are lacking.	Specification Status A specification for the item has been prepared but is under review or revision. Operating Program Characteristics The OPC have been substantially defined but are under review or revision.
COST METHODS AND DATA	Methods The estimate is almost a poor guess and little or no confidence can be placed in it. Data An almost total lack of current and reliable relevant data make the cost estimate completely uncertain.	Methods A highly arbitrary rule-of-thumb has been used. Data The data used to make the estimate highly suspect, very sparse in quantity, and characterized by major inconsistencies.	Methods A commonly used rule-of-thumb cost factor but with no supporting backup has been used. Data The data used have been obtained from official or standard sources. Notable inconsistencies, lack of currency, gaps in data reduce the confidence in the estimate.	Methods The basic method used to derive the cost is well documented but no double-check or authentication has been possible Data The data used are generally relevant and from a reputable source. They are incomplete, preliminary, or not completely current however.

COST DATA FORM - A(1)
NON-RECURRING (DDT E)

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	EXPECTED COST	CONFID RATING	$\bar{T}_D$	T_S	SPREAD FUNCT.
10	PROJECT MGT.	4	33.29	3.0	69	61	0
20	SYST. ENGR. + INT	4	94.24	3.0	81	61	30
2001	MOSC SYST. ENGR	5	53.35	3.0	66	61	30
2002	MODULE TO ORB. INT.	5	3.34	3.0	48	28	30
2003	INTGR. MOD. TO MOD.	5	37.54	3.0	60	40	30
30	MOSC-ALL MODULES	4	293.89	3.0	78	61	59
31	LOGISTIC MOD.	4.5	41.16	3.0	78	61	60
32	HABITABILITY MOD.	4.5	99.75	3.0	78	61	59
33	SUBSYST.MOD.	4.5	144.71	3.0	78	61	59
34	PAYLD. MOD.	4.5	8.27	3.0	78	61	59
3101	INTGR. ASSY.	5	5.64	3.0	45	28	60
3102	STRUCT./MECH.	5	7.93	3.0	66	61	60
3103	ECLS	5	7.85	3.0	66	61	60
3104	CREW ACCOM.	5	1.57	3.0	57	52	60
3105	ELECTRICAL POWER	5	14.43	3.0	54	49	59
3106	COMMUNICATIONS	5	.02	3.0	54	49	57
3109	PROPULSION	5	.74	3.0	60	55	58
3110	ENVIRON. PROT.	5	3.00	3.0	66	61	60
3201	INTGR. ASSY.	5	11.96	3.0	45	28	60
3202	STRUCT./MECH.	5	6.99	3.0	66	61	59
3203	ECLS	5	12.52	3.0	66	61	58
3204	CREW ACCOM.	5	11.60	3.0	57	52	59
3205	ELECTRICAL POWER	5	27.48	3.0	54	49	59
3206	COMMUNICATIONS	5	15.78	3.0	54	49	58
3207	DATA MANAGEMENT	5	10.06	3.0	66	61	58
3209	PROPULSION	5	.33	3.0	60	55	58
3210	ENVIRON. PROT.	5	3.03	3.0	66	61	60
3301	INTGR. ASSY.	5	14.58	3.0	45	28	60
3302	STRUCT./MECH.	5	11.48	3.0	66	61	[illegible]
3303	ECLS	5	26.42	3.0	66	61	59
3304	CREW ACCOM.	5	9.72	3.0	57	52	59
3305	ELECTRICAL POWER	5	63.91	3.0	54	49	57
3306	COMMUNICATIONS	5	3.32	3.0	54	49	57
3307	DATA MANAGEMENT	5	6.61	3.0	66	61	56
3308	STABIL. CONTROL	5	5.69	3.0	60	55	55
3309	PROPULSION	5	.33	3.0	60	55	55
3310	ENVIRON. PROT.	5	2.65	3.0	66	61	60
3401	INTGR. ASSY.	5	1.96	3.0	45	28	60
3402	STRUCT./MECH.	5	3.63	3.0	66	61	59
3410	ENVIRON. PROT.	5	2.69	3.0	66	61	60

COST DATA FORM - A(1)
NON-RECURRING (DDT E)

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	EXPECTED COST	CONFID RATING	T_D	T_S	SPREAD FUNCT.
40	EXPERIMENTS	4	.00	3.0	0	0	0
50	EXPER. INTEGRATION	4	.00	3.0	0	0	0
60	GSE	4	62.03	3.0	63	61	30
6001	ELECTRICAL	5	16.64	3.0	63	61	30
6002	MECHANICAL	5	5.04	3.0	63	61	30
6003	HYDRAULIC	5	14.37	3.0	63	61	30
6004	SOFTWARE	5	12.39	3.0	63	61	30
6005	LAUNCH EQUIP.	5	1.20	3.0	63	61	30
6006	FLIGHT SUPPORT	5	12.39	3.0	63	61	30
70	SYST. TEST EVAL	4	83.69	3.0	45	52	40
7001	MAJOR TEST ART.	5	55.46	3.0	45	52	40
7002	SYSTEM TEST	5	28.24	3.0	12	19	40
80	LOGISTICS	4	.00	3.0	0	0	0
8002	TRANSPORTATION	5	.00	3.0	0	0	0
90	FACILITIES	4	4.25	3.0	27	43	50

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COST DATA FORM - A(1)
NON-RECURRING (DDT E)

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	EXPECTED COST	CONFID RATING	T D	T S	SPREAD FUNCT.
10	PROJECT MGT.	4	33.29	3.0	69	61	0
20	SYST. ENGR. + INT	4	94.24	3.0	81	61	30
30	MOSC-ALL MODULES	4	293.69	3.0	78	61	59
40	EXPERIMENTS	4	.00	3.0	20	61	0
50	EXPER. INTEGRATION	4	.00	3.0	20	61	0
60	GSE	4	62.03	3.0	63	61	30
70	SYST. TEST EVAL	4	83.69	3.0	45	52	40
80	LOGISTICS	4	.00	3.0	18	25	0
90	FACILITIES	4	4.25	3.0	27	43	50
0	TOTAL	3	571.39	3.0	81	61	45

Appendix D

NASA COST DATA FORM A(2) - RECURRING (PRODUCTION)

This appendix presents the subject forms for WBS elements through subsystem Level 5. The definitions of each column on the form are as follows:

Number of Units: The quantity of units for each WBS item produced in the production phase of the program.

First Unit (T_1) Cost: The production cost or the theoretical first hardware unit. It is considered to be the Y-axis intercept of the learning curve on a log-log plot. The LEADER II cost model prints out this cost under the title of "Memo T_1" for WBS items 20 and 30. Systems Engineering and Integration and MOSC - All Modules, respectively, and subordinate elements thereof.

Expected Cost: For each WBS item costs, the total cumulative cost for the number of units of flight articles produced.

Reference Unit: The production sequence number of the first unit that is used in the recurring phase of the program.

Reference Unit Cost: The cost of the reference unit. At subordinate levels the cost is the specific cost of the reference unit. At summary levels the cost is the weighted average of the constituent subordinate reference units.

Confidence Rating: This column is discussed in Appendix C.

Td: Generally is the time in months required to produce, assemble, and perform acceptance tests on the designated WBS line item.

Ts: The lead time in months measured from the start of Td to the IOC, the launch milestone date.

Spread Function: Reference Appendix C.

Learning Index: A numerical index of a learning rate related to the recurring cost. A straight line cumulative average index is used in these calculations. At summary levels the learning indices of constituent WBS elements at subordinate levels.

COST DATA FORM - A(2)
RECURRING (PRODUCTION)

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	NO. OF UNITS	1ST UNIT COST T_1	EXPECTED COST	REF UNIT	REF UNIT COST	CONFID RATING	T_D	T_S	SPREAD FUNCT.	LEARN INDEX
10	PROJECT MGT.	4	1.0	.00	14.93	1	14.93	3.0	60	34	0	100
20	SYST. ENGR. + INT	4	1.0	25.21	100.63	1	100.63	3.0	63	34	47	100
2001	MOSC SYST. ENGR	5	1.0	.00	14.42	1	14.42	3.0	57	34	50	100
2002	MODULE TO ORB. INT.	5	1.0	.00	3.62	1	3.62	3.0	42	13	50	100
2003	INTGR. MOD. TO MOD.	5	1.0	25.21	49.20	1	49.20	3.0	42	13	50	100
2004	SUST. ENGR.	5	1.0	.00	33.39	1	33.39	3.0	36	7	40	100
30	MOSC-ALL MODULES	4	.0	100.84	197.78	1	131.65	3.0	72	49	50	95
31	LOGISTIC MOD.	4.5	.0	8.74	29.39	1	15.09	3.0	63	40	50	96
32	HABITABILITY MOD.	4.5	.0	31.92	57.79	1	40.76	3.0	63	40	50	94
33	SUBSYST.MOD.	4.5	.0	56.52	101.31	1	71.82	3.0	72	49	50	95
34	PAYLD. MOD.	4.5	.0	3.66	9.30	3	3.98	3.0	63	40	50	95
3101	INTGR. ASSY.	5	.0	1.33	4.46	1	4.46	3.0	48	25	50	100
3102	STRUCT./MECH.	5	.0	2.85	9.24	1	3.33	3.0	63	40	50	91
3103	ECLS	5	.0	.23	.77	1	.39	3.0	57	34	47	94
3104	CREW ACCOM.	5	.0	.20	.67	1	.32	3.0	54	31	50	94
3105	ELECTRICAL POWER	5	.0	2.33	8.42	1	3.85	3.0	54	31	50	97
3106	COMMUNICATIONS	5	.0	.01	.05	1	.02	3.0	57	34	50	94
3109	PROPULSION	5	.0	1.55	5.04	1	2.40	3.0	57	34	50	94
3110	ENVIRON. PROT.	5	.0	.23	.74	1	.30	3.0	54	31	50	93
3201	INTGR. ASSY.	5	.0	4.87	8.77	1	8.77	3.0	48	25	50	100
3202	STRUCT./MECH.	5	.0	3.09	4.23	1	2.34	3.0	63	40	50	91
3203	ECLS	5	.0	5.90	10.69	1	7.12	3.0	57	34	50	93
3204	CREW ACCOM.	5	.0	2.77	4.96	1	3.30	3.0	54	31	50	93
3205	ELECTRICAL POWER	5	.0	4.21	7.64	1	5.08	3.0	54	31	50	93
3206	COMMUNICATIONS	5	.0	7.29	13.04	1	8.67	3.0	57	34	50	93
3207	DATA MANAGEMENT	5	.0	2.99	5.49	1	3.63	3.0	54	31	50	94
3209	PROPULSION	5	.0	.32	2.07	1	1.30	3.0	57	34	50	93
3210	ENVIRON. PROT.	5	.0	.50	.90	1	.55	3.0	54	31	50	92
3301	INTGR. ASSY.	5	.0	8.62	15.37	1	15.37	3.0	48	25	50	100
3301	STRUCT./MECH.	5	.0	3.39	5.22	1	2.98	3.0	63	40	50	91
3303	ECLS	5	.0	8.16	14.80	1	9.86	3.0	57	34	50	93
3304	CREW ACCOM.	5	.0	4.69	8.43	1	5.61	3.0	54	49	50	93
3305	ELECTRICAL POWER	5	.0	21.10	38.28	1	25.49	3.0	54	31	50	93
3306	COMMUNICATIONS	5	.0	2.69	4.46	1	2.96	3.0	57	34	50	93
3307	DATA MANAGEMENT	5	.0	3.17	5.76	1	3.84	3.0	54	31	50	93
3308	STABIL. CONTROL	5	.0	4.10	7.91	1	5.03	3.0	57	34	50	97
3309	PROPULSION	5	.0	.26	.48	1	.31	3.0	57	34	50	97
3310	ENVIRON. PROT.	5	.0	.33	.60	1	.37	3.0	54	31	50	92
3401	INTGR. ASSY.	5	.0	.56	1.42	1	1.42	3.0	48	25	50	100
3402	STRUCT./MECH.	5	.0	2.76	6.51	1	2.06	3.0	63	40	50	92
3410	ENVIRON. PROT.	5	.0	.35	1.30	1	.51	3.0	54	31	50	93

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COST DATA FORM - A(2).
RECURRING (PRODUCTION)

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	NO.OF UNITS	1ST UNIT COST T1	EXPECTED COST	REF UNIT	REF UNIT COST	CONFID RATING	T D	T S	SPREAD FUNCT.	LEARN INDEX
40	EXPERIMENTS	4	1.0	.00	.00	1	.00	3.0	0	0	0	100
50	EXPER. INTEGRATION	4	1.0	.00	.00	1	.00	3.0	0	0	0	100
60	GSE	4	.0	.00	.27	1	.27	3.0	30	19	40	100
6001	ELECTRICAL	5	.0	.00	.03	1	.03	3.0	30	19	40	100
6002	MECHANICAL	5	.0	.00	.01	1	.01	3.0	30	19	40	100
6003	HYDRAULIC	5	.0	.00	.00	1	.00	3.0	30	19	40	100
6004	SOFTWARE	5	.0	.00	.11	1	.11	3.0	30	19	40	100
6005	LAUNCH EQUIP.	5	.0	.00	.00	1	.00	3.0	30	19	40	100
6006	FLIGHT SUPPORT	5	.0	.00	.11	1	.11	3.0	30	19	40	100
80	LOGISTICS	4	1.0	.00	.00	1	.00	3.0	0	0	0	100
90	FACILITIES	4	1.0	.00	.00	1	.00	3.0	0	0	0	100

COST DATA FORM - A(2)
RECURRING (PRODUCTION)

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	NO. OF UNITS	1ST UNIT COST T_1	EXPECTED COST	REF UNIT	REF UNIT COST	CONFID RATING	T_D	T_S	SPREAD FUNCT.	LEARN INDEX
10	PROJECT MGT.	4	1.0	.00	14,93	1	14.93	3.0	60	34	0	100
20	SYST. ENGR. + INT	4	1.0	25,21	100,63	1	100.63	3.0	63	34	49	100
30	MOSC-ALL MODULES	4	.0	100,84	197,78	1	131.65	3.0	72	49	50	95
40	EXPERIMENTS	4	1.0	.00	.00	1	.00	3.0	10	37	0	100
50	EXPER. INTEGRATION	4	1.0	.00	.00	1	.00	3.0	10	37	0	100
60	GSE	4	.0	.00	.27	1	.27	3.0	30	19	40	100
80	LOGISTICS	4	1.0	.00	.00	1	.00	3.0	24	7	0	100
90	FACILITIES	4	1.0	.00	.00	1	.00	3.0	36	43	50	100
0	TOTAL	3	1.0	126,06	313,61	1	247.48	3.0	78	47	47	97

Appendix E

NASA COST DATA FORM A(3) - RECURRING (OPERATIONS)

The subject forms for WBS elements through Subsystem Level 5 are included in this appendix. Definitions of each column on the form are as follows:

Identification Number: The appropriate WBS code corresponding to the item of cost.

WBS Identification: The alphanumeric nomenclature of the item from the WBS.

WBS Level: The level at which the cost is accumulated;

Level 3 - Program

Level 4 - System (Integrated Modules)

Level 4.5 - System (Individual Modules)

Level 5 - Subsystem

Number of Units: The quantity of units for each WBS item used in the operations phase of the program.

Expected Cost: For each WBS item, the total cumulative cost for the number of units of flight articles produced.

Reference Unit: The production sequence number of the first unit that is used in the recurring phase of the program.

Reference Unit Cost: The cost of the reference unit. At subordinate levels the cost is the specific cost of the reference unit. At summary levels the cost is the weighted average of the constituent subordinate reference units.

Confidence Rating: This column is discussed in Appendix C.

Td: Generally is the time in months from the start of ground system installation and test procedures verification through completion of flight evaluation.

Ts: The lead time in months measured from the start of Td to IOC, the launch milestone date.

Spread Functions: Reference Appendix C.

Learning Index: A straight line cumulative average index is used in these calculations. At summary levels the learning index is the weighted average of the learning indices of constituent WBS elements at subordinate levels.

COST DATA FORM - A(3)
RECURRING (OPERATIONS)

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	NO. OF UNITS	EXPECTED COST	REF UNIT	REF UNIT COST	CONFID RATING	T D	T S	SPREAD FUNCT.	LEARN INDEX
10	PROJECT MGT.	4	1.0	14.03	1	14.03	3.0	66	7	0	100
20	SYST. ENGR. + INT	4	1.0	7.96	1	1.59	3.0	66	7	0	100
2004	SUST. ENGR.	5	1.0	7.96	1	1.59	3.0	66	7	0	100
30	MOSC-ALL MODULES	4	.0	112.35	1	106.87	3.0	66	7	0	90
31	LOGISTIC MOD.	4.5	.0	15.72	1	15.72	3.0	33	7	0	90
32	HABITABILITY MOD.	4.5	.0	37.25	1	31.77	3.0	66	7	0	90
33	SUBSYST.MOD.	4.5	.0	59.22	1	59.22	3.0	66	7	0	90
34	PAYLD. MOD.	4.5	.0	.16	1	.16	3.0	33	7	0	90
3102	STRUCT./MECH.	5	.0	.14	1	.14	3.0	24	7	0	90
3103	ECLS	5	1.0	5.07	1	5.07	3.0	24	-2	0	90
3104	CREW ACCOM.	5	.9	.38	1	.38	3.0	24	-2	0	90
3105	ELECTRICAL POWER	5	1.0	5.90	1	5.90	3.0	24	-2	0	90
3106	COMMUNICATIONS	5	1.0	.03	1	.03	3.0	24	1	0	90
3109	PROPULSION	5	1.0	4.18	1	4.18	3.0	24	-2	0	90
3110	ENVIRON. PROT.	5	.0	.02	1	.02	3.0	24	-2	0	90
3202	STRUCT./MECH.	5	.0	.06	1	.06	3.0	24	7	0	90
3203	ECLS	5	1.0	9.13	1	9.13	3.0	24	-2	0	90
3204	CREW ACCOM.	5	.9	9.66	1	3.59	3.0	66	7	0	91
3205	ELECTRICAL POWER	5	1.0	5.35	1	5.35	3.0	24	-2	0	90
3206	COMMUNICATIONS	5	1.0	8.48	1	8.48	3.0	24	1	0	90
3207	DATA MANAGEMENT	5	1.0	3.39	1	3.39	3.0	24	-2	0	90
3209	PROPULSION	5	1.0	.40	1	.40	3.0	24	-2	0	90
3210	ENVIRON. PROT.	5	.0	.04	1	.04	3.0	24	-2	0	90
3302	STRUCT./MECH.	5	.0	.08	1	.08	3.0	24	7	0	90
3303	ECLS	5	1.0	12.64	1	12.64	3.0	24	-2	0	90
3304	CREW ACCOM.	5	.9	6.23	1	6.23	3.0	66	7	0	90
3305	ELECTRICAL POWER	5	1.0	26.83	1	26.83	3.0	24	-2	0	90
3306	COMMUNICATIONS	5	1.0	2.90	1	2.90	3.0	24	1	0	90
3307	DATA MANAGEMENT	5	1.0	3.55	1	3.55	3.0	24	-2	0	90
3308	STABIL. CONTROL	5	1.0	6.56	1	6.56	3.0	24	-2	0	90
3309	PROPULSION	5	1.0	.40	1	.40	3.0	24	-2	0	90
3310	ENVIRON. PROT.	5	.0	.03	1	.03	3.0	24	-2	0	90
3402	STRUCT./MECH.	5	.0	.10	1	.10	3.0	24	7	0	90
3410	ENVIRON. PROT.	5	.0	.06	1	.06	3.0	24	-2	0	90

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COST DATA FORM - A(3)
RECURRING (OPERATIONS)

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	NO. OF UNITS	EXPECTED COST	REF UNIT	REF UNIT COST	CONFID RATING	T_D	T_S	SPREAD FUNCT.	LEARN INDEX
60	GSE	4	.0	12.32	1	12.32	3.0	24	4	0	100
6001	ELECTRICAL	5	.2	3.60	1	3.60	3.0	24	4	0	100
6002	MECHANICAL	5	.0	.02	1	.02	3.0	24	4	0	100
6003	HYDRAULIC	5	.3	3.66	1	3.66	3.0	24	4	0	100
6004	SOFTWARE	5	.2	2.37	1	2.37	3.0	24	4	0	100
6005	LAUNCH EQUIP.	5	.3	.30	1	.30	3.0	24	4	0	100
6006	FLIGHT SUPPORT	5	.2	2.37	1	2.37	3.0	24	4	0	100
80	LOGISTICS	4	1.0	111.08	1	110.17	3.0	66	7	0	100
8001	TRAINING-CONSULT.	5	1.0	.37	1	.07	3.0	66	7	0	100
8002	TRANSPORTATION	5	1.0	.74	1	.32	3.0	66	7	0	100
8003	INVENT. CONTROL	5	1.0	.29	1	.06	3.0	66	7	0	100
8004	TRAINING AIDS	5	1.0	25.21	1	25.21	3.0	66	7	0	100
8005	SIMULATOR	5	1.0	84.47	1	84.47	3.0	66	7	0	100
90	FACILITIES	4	1.0	.00	1	.00	3.0	0	0	0	100
100	GROUND OPS.	4	1.0	41.81	1	3.48	3.0	66	7	0	100
10001	FLIGHT TEST	5	1.0	.00	1	.00	3.0	0	0	0	100
10002	MAINT./REFURB.	5	1.0	8.64	1	.72	3.0	66	7	0	100
10003	LAUNCH OPS.	5	1.0	24.77	1	2.06	3.0	66	7	0	100
10004	NON LAUNCH SITE	5	1.0	8.40	1	.70	3.0	66	7	0	100
110	FLIGHT OPS.	4	1.0	.00	1	.00	3.0	0	0	0	100

COST DATA FORM - A(3)
RECURRING (OPERATIONS)

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	NO. OF UNITS	EXPECTED COST	REF UNIT	REF UNIT COST	CONFID RATING	T D	T S	SPREAD FUNCT.	LEARN INDEX
10	PROJECT MGT.	4	1.0	14.03	1	14.03	3.0	66	7	0	100
20	SYST. ENGR. + INT.	4	1.0	7.96	1	1.59	3.0	66	7	0	100
30	MOSC-ALL MODULES	4	.0	112.35	1	106.87	3.0	66	7	0	90
60	GSE	4	.0	12.32	1	12.32	3.0	24	4	0	100
80	LOGISTICS	4	1.0	111.08	1	110.13	3.0	66	7	0	100
90	FACILITIES	4	1.0	.00	1	.00	3.0	66	7	0	100
100	GROUND OPS.	4	1.0	41.81	1	3.48	3.0	66	7	0	100
110	FLIGHT OPS.	4	1.0	.00	1	.00	3.0	66	7	0	100
0	TOTAL	3	1.0	299.55	1	248.42	3.0	66	7	0	95

Appendix F
NASA COST DATA FORM C - FUNDING DISTRIBUTION

This appendix contains the time-phased cost estimates required to accomplish the DDT&E, production, and operations phases for each WBS element of the four-man MOSC program. Funding by FY is displayed on Cost Data Form C through the Subsystem Level - Level 5 for each one of the three phases.

GRAPHIC FUNDING BY PHASE - LEVELS 3 AND 4

This subsection presents summary charts for the following WBS elements:

WBS No.	Level	Identification
	3	Manned Orbital Systems Concept
10	4	Project Management
20	4	Systems Engineering and Integration
30	4	MOSC - All Modules
60	4	Ground Support Equipment
70	4	System Test
80	4	Logistics
90	4	Facilities
100	4	Ground Operations

No summary charts are provided for the following Level 4 WBS elements:

WBS No.	Identification	Reason for Omission
40	Integral Experiments	Government furnished
50	Experiment Integration	No definition
110	Flight Operations	No flight test in program

FUNDING SCHEDULE
DATA FORM C

X NON RECURRING(DDT E)

WBS NUMBER	WBS NAME	FY 80	FY 81	FY 82	FY 83	FY 84	FY 85	FY 86	FY 87	FY 88	FY 89	FY 90
							DOLLARS IN MILLIONS					
	TOTAL PROJ PHASE	9.1	53.9	155.1	173.4	130.0	40.3	9.5	.0	.0	.0	.0
10	PROJECT MGT.	3.5	5.9	6.3	6.3	6.3	5.0	.0	.0	.0	.0	.0
20	SYST. ENGR. + INT	.4	4.5	12.0	22.0	27.5	19.7	8.0	.0	.0	.0	.0
2001	HOSC SYST. ENGR	.4	4.5	11.1	16.4	15.8	5.2	.0	.0	.0	.0	.0
2002	MODULE TO ORB. INT.	.0	.0	.0	.2	.8	1.4	.9	.0	.0	.0	.0
2003	INTGR. MOD. TO MOD.	.0	.0	.9	5.4	10.9	13.1	7.1	.0	.0	.0	.0
30	HOSC-ALL MODULES	4.6	32.7	99.5	97.6	45.5	12.4	1.5	.0	.0	.0	.0
31	LOGISTIC MOD.	.9	5.5	12.6	13.0	6.9	2.0	.2	.0	.0	.0	.0
3101	INTGR. ASSY.	.0	.0	.0	1.2	2.5	1.7	.2	.0	.0	.0	.0
3102	STRUCT./MECH.	.4	2.0	2.8	1.9	.7	.0	.0	.0	.0	.0	.0
3103	ECLS	.4	1.6	2.6	2.3	.9	.1	.0	.0	.0	.0	.0
3104	CREW ACCOM.	.0	.2	.6	.6	.2	.0	.0	.0	.0	.0	.0
3105	ELECTRICAL POWER	.0	1.1	5.3	5.8	2.1	.1	.0	.0	.0	.0	.0
3106	COMMUNICATIONS	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3109	PROPULSION	.0	.1	.3	.2	.1	.0	.0	.0	.0	.0	.0
3110	ENVIRON. PROT.	.1	.5	1.0	.9	.4	.0	.0	.0	.0	.0	.0
32	HABITABILITY MOD.	1.3	10.7	33.8	32.6	16.4	4.4	.5	.0	.0	.0	.0
3201	INTGR. ASSY.	.0	.0	.0	2.5	5.3	3.6	.5	.0	.0	.0	.0
3202	STRUCT./MECH.	.3	1.8	2.5	1.7	.7	.0	.0	.0	.0	.0	.0
3203	ECLS	.4	2.0	5.4	3.4	1.2	.1	.0	.0	.0	.0	.0
3204	CREW ACCOM.	.0	1.5	4.1	4.4	1.5	.1	.0	.0	.0	.0	.0
3205	ELECTRICAL POWER	.0	2.1	10.2	11.1	3.9	.2	.0	.0	.0	.0	.0
3206	COMMUNICATIONS	.0	.8	6.3	5.9	2.6	.2	.0	.0	.0	.0	.0
3207	DATA MANAGEMENT	.4	1.8	4.3	2.6	.9	.1	.0	.0	.0	.0	.0
3209	PROPULSION	.0	.0	.1	.2	.0	.0	.0	.0	.0	.0	.0
3210	ENVIRON. PROT.	.2	.7	1.0	.8	.3	.0	.0	.0	.0	.0	.0
33	SUBSYST. MOD.	2.1	15.0	50.9	49.9	20.7	5.3	.7	.0	.0	.0	.0
3301	INTGR. ASSY.	.0	.0	.0	3.1	6.4	4.4	.7	.0	.0	.0	.0
3302	STRUCT./MECH.	.6	2.7	3.8	3.4	.9	.0	.0	.0	.0	.0	.0
3303	ECLS	1.2	5.2	10.2	7.1	2.5	.2	.0	.0	.0	.0	.0
3304	CREW ACCOM.	.0	1.2	3.7	3.5	1.2	.1	.0	.0	.0	.0	.0
3305	ELECTRICAL POWER	.0	4.0	25.1	26.8	7.6	.4	.0	.0	.0	.0	.0
3306	COMMUNICATIONS	.0	.0	1.4	1.2	.6	.1	.0	.0	.0	.0	.0
3307	DATA MANAGEMENT	.2	.9	3.2	1.8	.6	.1	.0	.0	.0	.0	.0
3308	STABIL. CONTROL	.0	.4	2.7	2.1	.5	.0	.0	.0	.0	.0	.0
3309	PROPULSION	.0	.0	.2	.1	.0	.0	.0	.0	.0	.0	.0
3310	ENVIRON. PROT.	.1	.6	.9	.8	.3	.0	.0	.0	.0	.0	.0
34	PAYLD. MOD.	.3	1.5	2.2	2.1	1.5	.6	.1	.0	.0	.0	.0
3401	INTGR. ASSY.	.0	.0	.0	.4	.9	.6	.1	.0	.0	.0	.0
3402	STRUCT./MECH.	.2	.9	1.3	.9	.4	.0	.0	.0	.0	.0	.0
3410	ENVIRON. PROT.	.1	.6	.9	.7	.3	.0	.0	.0	.0	.0	.0
40	EXPERIMENTS	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
50	EXPER. INTEGRATION	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
60	GSE	.6	5.9	14.4	20.4	17.7	3.1	.0	.0	.0	.0	.0
6001	ELECTRICAL	.2	1.6	3.9	5.5	4.7	.8	.0	.0	.0	.0	.0
6002	MECHANICAL	.0	.5	1.2	1.7	1.4	.3	.0	.0	.0	.0	.0
6003	HYDRAULIC	.1	1.4	3.3	4.7	4.1	.7	.0	.0	.0	.0	.0

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FUNDING SCHEDULE
DATA FORM C

X NON RECURRING(DDT E)

WBS NUMBER	WBS NAME	FY 80	FY 81	FY 82	FY 83	FY 84	FY 85	FY 86	FY 87	FY 88	FY 89	FY 90
		DOLLARS IN MILLIONS										
6004	SOFTWARE	.1	1.2	2.9	4.1	3.5	.6	.0	.0	.0	.0	.0
6005	LAUNCH EQUIP.	.0	.1	.3	.4	.3	.1	.0	.0	.0	.0	.0
6006	FLIGHT SUPPORT	.1	1.2	2.9	4.1	3.5	.6	.0	.0	.0	.0	.0
70	SYST. TEST EVAL	.0	4.9	20.4	25.4	33.0	.0	.0	.0	.0	.0	.0
7001	MAJOR TEST ART.	.0	4.9	20.4	23.3	6.8	.0	.0	.0	.0	.0	.0
7002	SYSTEM TEST	.0	.0	.0	2.1	26.1	.0	.0	.0	.0	.0	.0
80	LOGISTICS	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
8002	TRANSPORTATION	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
90	FACILITIES	.0	.0	2.8	1.7	.0	.0	.0	.0	.0	.0	.0

FUNDING SCHEDULE
DATA FORM C

X NON RECURRING (DDT E)

WBS NUMBER	WBS NAME	FY 80	FY 81	FY 82	FY 83	FY 84	FY 85	FY 86	FY 87	FY 88	FY 89	FY 90
		DOLLARS IN MILLIONS										
10	PROJECT MGT.	3.5	5.9	6.3	6.3	6.3	5.0	.0	.0	.0	.0	.0
20	SYST. ENGR. + INT	.4	4.5	12.0	22.0	27.5	19.7	8.0	.0	.0	.0	.0
30	HOSC-ALL MODULES	4.6	32.7	99.5	97.6	45.5	12.4	1.5	.0	.0	.0	.0
40	EXPERIMENTS	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
50	EXPER. INTEGRATION	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
60	GSE	.6	5.9	14.4	20.4	17.7	3.1	.0	.0	.0	.0	.0
70	SYST. TEST EVAL	.0	4.9	20.4	25.4	33.0	.0	.0	.0	.0	.0	.0
80	LOGISTICS	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
90	FACILITIES	.0	.0	2.5	1.7	.0	.0	.0	.0	.0	.0	.0
	TOTAL PROJ PHASE	9.1	53.9	155.1	173.4	130.0	40.3	9.5	.0	.0	.0	.0

FUNDING SCHEDULE
DATA FORM C

X RECURRING(PRODUCTION)

WBS NUMBER	WBS NAME	FY 80	FY 81	FY 82	FY 83	FY 84	FY 85	FY 86	FY 87	FY 88	FY 89	FY 90
							DOLLARS IN MILLIONS					
	TOTAL PROJ PHASE	.0	.1	9.0	63.4	95.0	77.7	56.5	11.6	.0	.0	.0
10	PROJECT MGT.	.0	.0	1.5	3.0	3.0	3.0	3.0	1.5	.0	.0	.0
20	SYST. ENGR. + INT	.0	.0	.1	2.5	9.0	36.4	42.6	10.0	.0	.0	.0
2001	MOSC SYST. ENGR	.0	.0	.1	2.5	5.3	4.8	1.7	.0	.0	.0	.0
2002	MODULE TO ORB. INT.	.0	.0	.0	.0	.3	1.6	1.6	.3	.0	.0	.0
2003	INTGR. MOD. TO MOD.	.0	.0	.0	.0	3.4	21.2	21.2	3.4	.0	.0	.0
2004	SUST. ENGR.	.0	.0	.0	.0	.1	8.8	18.2	6.3	.0	.0	.0
30	MOSC-ALL MODULES	.0	.1	7.4	57.9	82.9	38.3	10.9	.1	.0	.0	.0
31	LOGISTIC MOD.	.0	.0	1.9	9.6	11.0	5.2	1.5	.0	.0	.0	.0
3101	INTGR. ASSY.	.0	.0	.0	.2	1.5	1.9	.8	.0	.0	.0	.0
3102	STRUCT./MECH.	.0	.0	1.8	5.1	2.0	.2	.1	.0	.0	.0	.0
3103	ECLS	.0	.0	.0	.2	.3	.2	.0	.0	.0	.0	.0
3104	CREW ACCOM.	.0	.0	.0	.2	.3	.1	.0	.0	.0	.0	.0
3105	ELECTRICAL POWER	.0	.0	.0	2.3	4.2	1.6	.4	.0	.0	.0	.0
3106	COMMUNICATIONS	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3109	PROPULSION	.0	.0	.1	1.4	2.3	1.0	.2	.0	.0	.0	.0
3110	ENVIRON. PROT.	.0	.0	.0	.2	.4	.1	.0	.0	.0	.0	.0
32	HABITABILITY MOD.	.0	.0	1.5	16.7	24.7	11.3	3.3	.0	.0	.0	.0
3201	INTGR. ASSY.	.0	.0	.0	.4	2.9	3.8	1.6	.0	.0	.0	.0
3202	STRUCT./MECH.	.0	.0	.8	2.3	.9	.1	.0	.0	.0	.0	.0
3203	ECLS	.0	.0	.2	3.4	4.8	1.9	.4	.0	.0	.0	.0
3204	CREW ACCOM.	.0	.0	.0	1.3	2.4	.9	.2	.0	.0	.0	.0
3205	ELECTRICAL POWER	.0	.0	.0	2.1	3.8	1.5	.3	.0	.0	.0	.0
3206	COMMUNICATIONS	.0	.0	.3	4.8	5.7	1.7	.5	.0	.0	.0	.0
3207	DATA MANAGEMENT	.0	.0	.0	1.5	2.7	1.0	.2	.0	.0	.0	.0
3209	PROPULSION	.0	.0	.0	.6	.9	.4	.1	.0	.0	.0	.0
3210	ENVIRON. PROT.	.0	.0	.0	.3	.5	.1	.0	.0	.0	.0	.0
33	SUBSYST.MOD.	.0	.1	2.7	27.4	44.4	20.8	5.7	.1	.0	.0	.0
3301	INTGR. ASSY.	.0	.0	.0	.7	5.2	6.7	2.7	.0	.0	.0	.0
3302	STRUCT./MECH.	.0	.0	1.0	2.9	1.2	.1	.0	.0	.0	.0	.0
3303	ECLS	.0	.0	.3	4.8	6.7	2.5	.5	.0	.0	.0	.0
3304	CREW ACCOM.	.0	.1	.9	3.0	3.6	.7	.0	.0	.0	.0	.0
3305	ELECTRICAL POWER	.0	.0	.1	10.3	18.9	7.3	1.6	.0	.0	.0	.0
3306	COMMUNICATIONS	.0	.0	.1	1.7	1.9	.6	.2	.0	.0	.0	.0
3307	DATA MANAGEMENT	.0	.0	.0	1.5	2.8	1.1	.2	.0	.0	.0	.0
3308	STABIL. CONTROL	.0	.0	.1	2.3	3.6	1.6	.3	.0	.0	.0	.0
3309	PROPULSION	.0	.0	.0	.1	.2	.1	.0	.0	.0	.0	.0
3310	ENVIRON. PROT.	.0	.0	.0	.2	.3	.1	.0	.0	.0	.0	.0
34	PAYLD. MOD.	.0	.0	1.3	4.1	2.6	1.0	.3	.0	.0	.0	.0
3401	INTGR. ASSY.	.0	.0	.0	.1	.5	.6	.3	.0	.0	.0	.0
3402	STRUCT./MECH.	.0	.0	1.3	3.6	1.4	.2	.1	.0	.0	.0	.0
3410	ENVIRON. PROT.	.0	.0	.0	.4	.7	.2	.0	.0	.0	.0	.0
40	EXPERIMENTS	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
50	EXPER. INTEGRATION	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
60	GSE	.0	.0	.0	.0	.1	.1	.0	.0	.0	.0	.0
6001	ELECTRICAL	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
6002	MECHANICAL.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

FUNDING SCHEDULE
DATA FORM C

X RECURRING(PRODUCTION)

		DOLLARS IN MILLIONS										
WBS NUMBER	WBS NAME	FY 80	FY 81	FY 82	FY 83	FY 84	FY 85	FY 86	FY 87	FY 88	FY 89	FY 90
6003	HYDRAULIC	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
6004	SOFTWARE	.0	.0	.0	.0	.0	.1	.0	.0	.0	.0	.0
6005	LAUNCH EQUIP.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
6006	FLIGHT SUPPORT	.0	.0	.0	.0	.0	.1	.0	.0	.0	.0	.0
80	LOGISTICS	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
8002	TRANSPORTATION	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
90	FACILITIES	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

FUNDING SCHEDULE
DATA FORM C

X RECURRING(PRODUCTION)

WBS NUMBER	WBS NAME	FY 80	FY 81	FY 82	FY 83	FY 84	FY 85	FY 86	FY 87	FY 88	FY 89	FY 90
		DOLLARS IN MILLIONS										
10	PROJECT MGT.	.0	.0	1.5	3.0	3.0	3.0	3.0	1.5	.0	.0	.0
20	SYST. ENGR. + INT	.0	.0	.1	2.5	9.0	36.4	42.6	10.0	.0	.0	.0
30	MOSC-ALL MODULES	.0	.1	7.4	57.9	82.9	38.3	10.9	.1	.0	.0	.0
40	EXPERIMENTS	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
50	EXPER. INTEGRATION	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
60	GSE	.0	.0	.0	.0	.1	.1	.0	.0	.0	.0	.0
80	LOGISTICS	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
90	FACILITIES	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	TOTAL PROJ PHASE	.0	.1	9.0	63.4	95.0	77.7	56.5	11.6	.0	.0	.0

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OF POOR QUALITY

FUNDING SCHEDULE
DATA FORM C

X RECURRING(OPERATIONS)

DOLLARS IN MILLIONS

WBS NUMBER	WBS NAME	FY 80	FY 81	FY 82	FY 83	FY 84	FY 85	FY 86	FY 87	FY 88	FY 89	FY 90
	TOTAL PROJ PHASE	.0	.0	.0	.0	7.9	67.2	92.1	57.9	32.9	32.9	8.6
10	PROJECT MGT.	.0	.0	.0	.0	.6	2.6	2.6	2.6	2.6	2.6	.6
1001	PROJECT MGT.	.0	.0	.0	.0	.6	2.6	2.6	2.6	2.6	2.6	.6
20	SYST. ENGR. + INT	.0	.0	.0	.0	.0	1.4	1.4	1.4	1.4	1.4	.7
2004	SUST. ENGR.	.0	.0	.0	.0	.0	1.4	1.4	1.4	1.4	1.4	.7
30	MOSC-ALL MODULES	.0	.0	.0	.0	.3	29.2	54.1	26.1	1.1	1.1	.3
31	LOGISTIC MOD.	.0	.0	.0	.0	.0	4.0	7.8	3.9	.0	.0	.0
3102	STRUCT./MECH.	.0	.0	.0	.0	.0	.1	.0	.0	.0	.0	.0
3103	ECLS	.0	.0	.0	.0	.0	1.3	2.5	1.3	.0	.0	.0
3104	CREW ACCOM.	.0	.0	.0	.0	.0	.1	.2	.1	.0	.0	.0
3105	ELECTRICAL POWER	.0	.0	.0	.0	.0	1.5	2.9	1.5	.0	.0	.0
3106	COMMUNICATIONS	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3108	STABIL. CONTROL	.0	.0	.0	.0	.0	1.0	2.1	1.0	.0	.0	.0
3110	ENVIRON. PROT.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
32	HABITABILITY MOD.	.0	.0	.0	.0	.3	10.0	16.6	7.8	1.1	1.1	.3
3202	STRUCT./MECH.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3203	ECLS	.0	.0	.0	.0	.0	2.3	4.6	2.3	.0	.0	.0
3204	CREW ACCOM.	.0	.0	.0	.0	.3	1.8	2.6	1.8	1.1	1.1	.3
3205	ELECTRICAL POWER	.0	.0	.0	.0	.0	1.3	2.7	1.3	.0	.0	.0
3206	COMMUNICATIONS	.0	.0	.0	.0	.0	3.2	4.2	1.1	.0	.0	.0
3207	DATA MANAGEMENT	.0	.0	.0	.0	.0	.8	1.7	.8	.0	.0	.0
3209	PROPULSION	.0	.0	.0	.0	.0	.4	.9	.4	.0	.0	.0
3210	ENVIRON. PROT.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
33	SUBSYST.MOD.	.0	.0	.0	.0	.0	15.2	29.6	14.4	.0	.0	.0
3302	STRUCT./MECH.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3303	ECLS	.0	.0	.0	.0	.0	3.2	6.3	3.2	.0	.0	.0
3304	CREW ACCOM.	.0	.0	.0	.0	.0	1.6	3.1	1.6	.0	.0	.0
3305	ELECTRICAL POWER	.0	.0	.0	.0	.0	6.7	13.4	6.7	.0	.0	.0
3306	COMMUNICATIONS	.0	.0	.0	.0	.0	1.1	1.4	.4	.0	.0	.0
3307	DATA MANAGEMENT	.0	.0	.0	.0	.0	.9	1.8	.9	.0	.0	.0
3308	STABIL. CONTROL	.0	.0	.0	.0	.0	1.6	3.3	1.6	.0	.0	.0
3309	PROPULSION	.0	.0	.0	.0	.0	.1	.2	.1	.0	.0	.0
3310	ENVIRON. PROT.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
34	PAYLD. MOD.	.0	.0	.0	.0	.0	.1	.1	.0	.0	.0	.0
3402	STRUCT./MECH.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3410	ENVIRON. PROT.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
60	GSE	.0	.0	.0	.0	.0	6.2	6.2	.0	.0	.0	.0
6001	ELECTRICAL	.0	.0	.0	.0	.0	1.8	1.8	.0	.0	.0	.0
6002	MECHANICAL	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
6003	HYDRAULIC	.0	.0	.0	.0	.0	1.8	1.8	.0	.0	.0	.0
6004	SOFTWARE	.0	.0	.0	.0	.0	1.2	1.2	.0	.0	.0	.0
6005	LAUNCH EQUIP.	.0	.0	.0	.0	.0	.1	.1	.0	.0	.0	.0
6006	FLIGHT SUPPORT	.0	.0	.0	.0	.0	1.2	1.2	.0	.0	.0	.0
80	LOGISTICS	.0	.0	.0	.0	5.0	20.2	20.2	20.2	20.2	20.2	5.0
8001	TRAINING-CONSULT.	.0	.0	.0	.0	.0	.1	.1	.1	.1	.1	.0
8002	TRANSPORTATION	.0	.0	.0	.0	.0	.1	.1	.1	.1	.1	.0
8003	INVENT. CONTROL	.0	.0	.0	.0	.0	.1	.1	.1	.1	.1	.0
8004	TRAINING AIDS	.0	.0	.0	.0	1.1	4.6	4.6	4.6	4.6	4.6	1.1

FUNDING SCHEDULE
DATA FORM C

X RECURRING(OPERATIONS)

DOLLARS IN MILLIONS

WBS NUMBER	WBS NAME	FY 80	FY 81	FY 82	FY 83	FY 84	FY 85	FY 86	FY 87	FY 88	FY 89	FY 90
8005	SIMULATOR	.0	.0	.0	.0	3.8	15.4	15.4	15.4	15.4	15.4	3.8
90	FACILITIES	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
100	GROUND OPS.	.0	.0	.0	.0	1.9	7.6	7.6	7.6	7.6	7.6	1.9
10001	FLIGHT TEST	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
10002	MAINT./REFURB.	.0	.0	.0	.0	.4	1.6	1.6	1.6	1.6	1.6	.4
10003	LAUNCH OPS.	.0	.0	.0	.0	1.1	4.5	4.5	4.5	4.5	4.5	1.1
10004	NON LAUNCH SITE	.0	.0	.0	.0	.4	1.5	1.5	1.5	1.5	1.5	.4
110	FLIGHT OPS.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

FUNDING SCHEDULE
DATA FORM C

X RECURRING(OPERATIONS)

DOLLARS IN MILLIONS

WBS NUMBER	WBS NAME	FY 80	FY 81	FY 82	FY 83	FY 84	FY 85	FY 86	FY 87	FY 88	FY 89	FY 90
10	PROJECT MGT.	.0	.0	.0	.0	.6	2.6	2.6	2.6	2.6	2.6	.6
20	SYST. ENGR. + INT	.0	.0	.0	.0	.0	1.4	1.4	1.4	1.4	1.4	.7
30	MOSC-ALL MODULES	.0	.0	.0	.0	.3	29.2	54.1	26.1	1.1	1.1	.3
60	GSE	.0	.0	.0	.0	.0	6.2	6.2	.0	.0	.0	.0
80	LOGISTICS	.0	.0	.0	.0	5.0	20.2	20.2	20.2	20.2	20.2	5.0
90	FACILITIES	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
100	GROUND OPS.	.0	.0	.0	.0	1.9	7.5	7.6	[illegible]	7.6	[illegible]	[illegible]
110	FLIGHT OPS.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
	TOTAL PROJ PHASE	.0	.0	.0	.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Appendix G
ALTERNATE VEHICLE CONFIGURATIONS

In addition to the four-man baseline, alternate configuration options included are a three-man austere configuration, as depicted in Figure G-1 and a six-man growth configuration shown in Figure G-2. The three-man austere configuration was chosen and configured to represent the smallest facility that would provide the advantages of an extended mission, free flying capability. A single, 60-day duration facility was chosen to represent this "lower-limit" because many of the experiments presently considered could be accommodated by a 60-day duration, and by using additional Shuttle flights the single facility could be recovered and repositioned into different orbits. The six-man facility was chosen to represent a larger facility mid-way between a four-man facility and the eight-man facility that could be obtained by joining two of the four-man baselines.

Rough comparative costs of these two options were estimated in relation to the baseline costs and are presented in Figure G-3. Project cost for the three-man, austere, single facility are estimated to be $780 million or $405 million less than the four-man baseline. The major change is in the production and operations costs and the major contributing factor in the decrease is not only the deletion of one complete set of flight hardware but also the combining/eliminating some of the modules in the remaining set. The six-man growth version maintains the two orbit capability. It is estimated to cost $255 million more than the baseline or $1.440 million. The cost for each phase of this configuration reflects the additional complexity and size of the expanded version. The operational costs not only reflect the cost of additional supplies, spares and launch operations but also reflect the additional cost of the larger simulator/trainer.

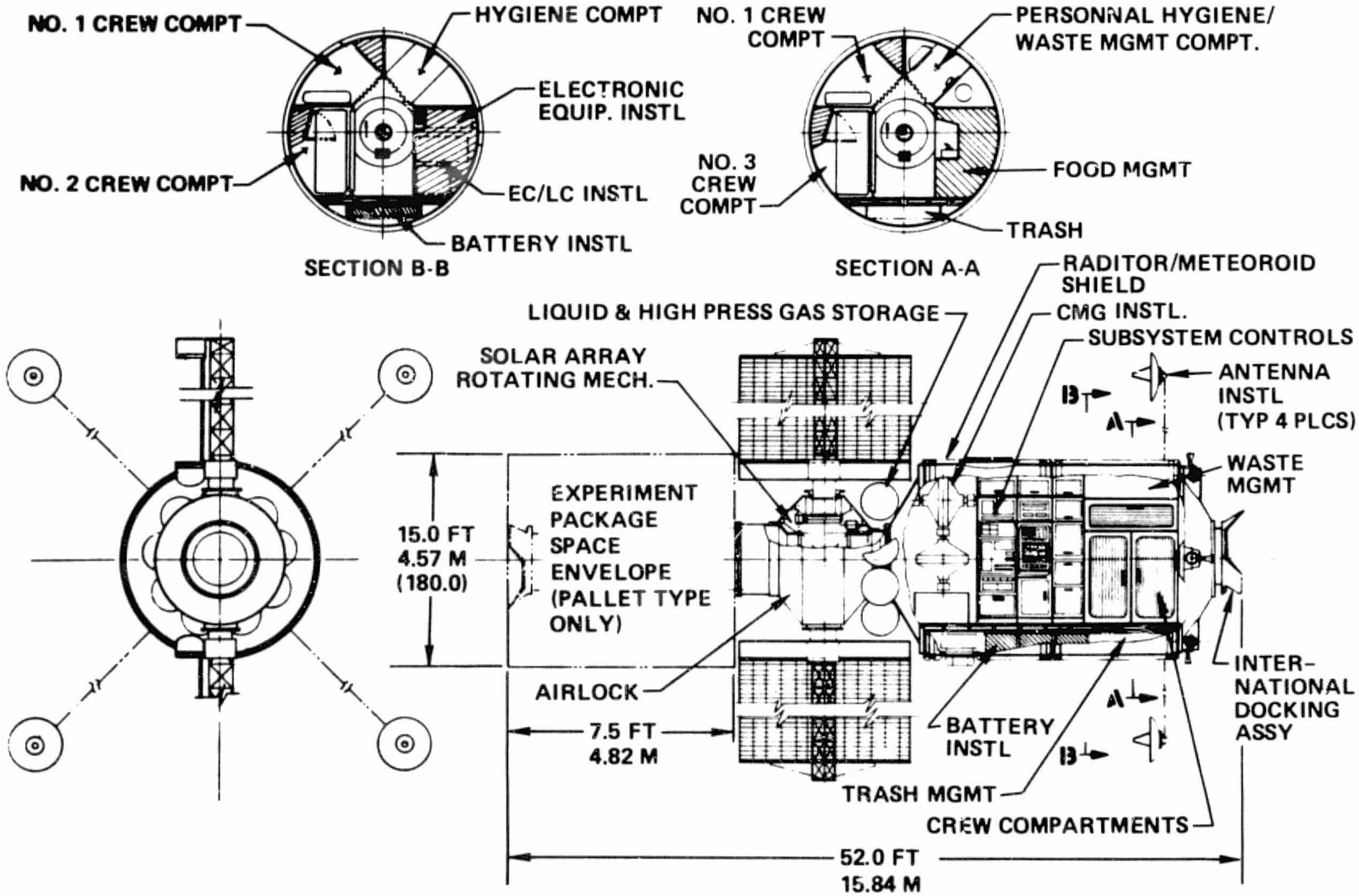

Figure G-1. MOSC 3-Man Limited – Duration Configuration

CR28

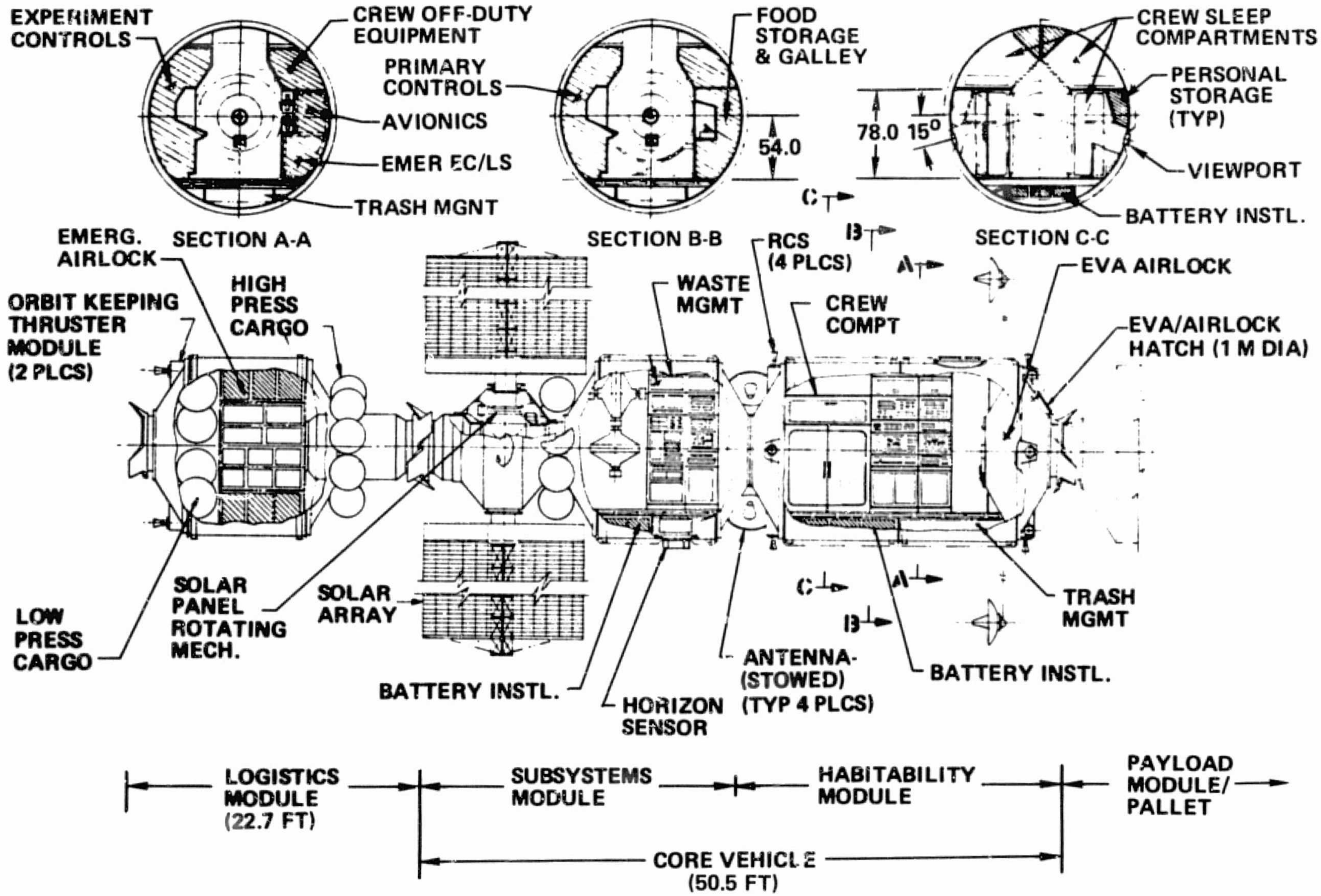

Figure G-2. MOSC 6-Man Growth Configuration

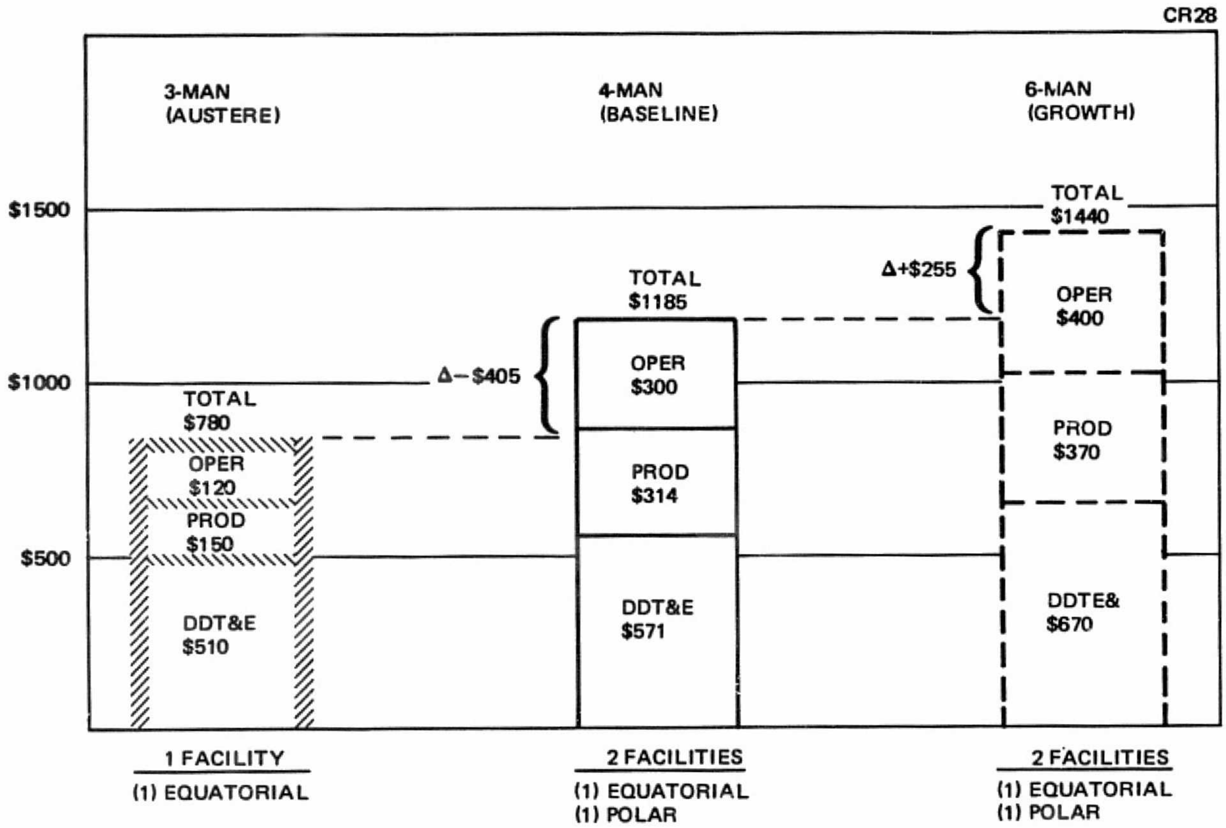

Figure G-3. Comparative Project Costs MOSC 3-, 4-, and 6-Man Configurations FY 1975 Dollars in Millions

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